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The Efficiency of the National Electricity Board in Malaysia - an Intercountry Comparison

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January 1996

SEEDS 84
ISBN 1-85237-165-X

Department of Economics
University of Surrey

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ISBN: 1-85237-165-X
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British Library Cataloguing-in-Publication Data.
A catalogue record for this book is available from the British Library.

ABSTRACT

One of the most pressing questions facing developing countries and the international agencies that finance their economic programmes is the appropriate way in which to operate and manage their power industries. Until recently, power industries have been regarded as public sector utilities to be operated as monopolies in order to achieve a variety of policy goals. Much international policy has been directed towards reducing the state's role in the electricity sector, and promoting efforts to privatise its management and ownership. This paper focuses on one aspect of economic performance, namely the efficiency with which electricity is generated. Evidence suggests that changes in the organisation of electricity generation can be justified on efficiency grounds. We make use of an increasingly popular non parametric technique - Data Envelopment Analysis - to analyse the case of Malaysia, a country which adopted a privatisation policy in the mid 1980s. One of the main arguments for the privatisation programme in Malaysia was that public enterprises were not efficient. We use unique data sets to compare the performance of its National Electricity Board with those of other countries in a similar stage of development, as well as with the major privatised Western electricity sector - that of the UK.

One of the most pressing questions facing developing countries and the international agencies that finance their economic programmes is the appropriate way in which to operate and manage their power industries. Until recently, power industries have been regarded as public sector utilities to be operated as monopolies in order to achieve a variety of policy goals. These tended to include, as noted by the World Bank (World Bank, 1993), not only the efficiency goal of low priced power but social equity objectives as well. Because making industry subserve social goals has been criticised by the Bank as 'costly and ineffective', much international policy has been directed towards reducing the state's role in the electricity sector, and promoting efforts to privatise its management and ownership. This paper focuses on one aspect of economic performance, namely the efficiency with which electricity is generated. Evidence suggests that changes in the organisation of electricity generation can be justified on efficiency grounds.

In order to show this result we make use of an increasingly popular non parametric technique - Data Envelopment Analysis - which has certain advantages over other methods of estimating production functions. Our analysis examines the case of Malaysia, a country which adopted a privatisation policy in the mid 1980s. One of the main arguments for the privatisation programme in Malaysia was that public enterprises were not efficient. We compare the performance of its National Electricity Board with those of other countries in a similar stage of development, as well as with the major privatised Western electricity sector - that of the UK.

1 PRODUCTIVITY AND THE MEASUREMENT OF EFFICIENCY

Productivity advancement is generally recognised as an important major contributing factor to economic growth. The measurement and analysis of aggregate productivity growth has been a significant research topic since World War 2 (Cowing and Stevenson, 1981). In contrast, the measurement of productivity level advancement at the firm level is a relatively new area of interest, especially in the case of public enterprises and regulated industries. Following the privatisation programmes in many countries productivity measurement has become an essential requirement for the privatised firms. Privatised firms have to calculate and publish measures of efficiency and productivity development as required by the regulator. The RPI-X+Y regulation regime places efficiency and productivity growth at the core of operational concern.

The objective of this paper is to evaluate the performance of the electricity sector in Malaysia using an intercountry comparison of productivity growth. It focuses on a performance comparison of the public utility firm (NEB) in Malaysia with that of Thailand (EGAT) and the United Kingdom (CEGB) using the output augmentation approach of Data Envelopment Analysis. Data Envelopment Analysis (DEA) as developed by Fare, Grosskopf and Lovell (1994) builds on methods devised by Charnes, Cooper and Rhodes (1978,1981) to implement Farrell's (1957) efficiency evaluation of the individual firm.

The paper is divided into six sections. Section 2 discusses briefly the Data Envelopment Analysis model based on Farrell's technical and allocative efficiency concept. Section 3 discusses the Malmquist productivity index using the Linear programming approach. Section 4 examines the technical or productive efficiency of NEB relative to 27 electricity utilities in other countries using cross section data. It also examines NEB's efficiency in relation to EGAT and CEGB using time series data from 1975 to 1990. Section 5 measures the productivity growth of NEB over time using the Malmquist Productivity Index approach. Section 6 summarises the result of the findings.

2 DATA ENVELOPMENT ANALYSIS

The DEA model uses a mathematical programming technique to estimate the efficient frontier. This contrasts with the traditional econometric approach which estimates an 'average' relationship between inputs and outputs. As noted by Seiford and Thrall (1990) the econometric approach has a number of weaknesses. In order to estimate the coefficients of the production function it requires the functional form to be pre-specified. The functional form will not in general be known, however, and adoption of an arbitrary functional form will produce misspecification errors. It does not readily yield a summary judgement on efficiency as only residuals are produced. The ability of the econometric model to identify sources of inefficiency is weak and is influenced by outliers. Finally, by estimating a function on the basis of average response it ignores the important distinction between firms which optimise their selection of inputs and those which do not. In contrast DEA is an extremal process, analyses each firm separately and measures its relative efficiency with respect to the entire set of decision making units (DMUs) being evaluated. It does not require *a priori* assumption on the analytic form of production function. A DEA-based production model can also accommodate a variable that is neither an economic resource nor a product such as attributes of the environment or the production process (Charnes *et al*, 1985). DEA provides solutions using standard techniques of linear programming and thus provides the benefits of computational efficiency, dual variables and clear interpretations. The empirical orientation[1] and absence of *a priori* assumptions has made it possible to measure efficiency from direct efficient frontier estimation in nonprofit, and regulated sectors as well as in profit maximising organisations.[2]

2.1 Theoretical perspective - Farrell's technical and allocative efficiency concept

This brief explanation of efficiency and data envelopment analysis relies heavily on the excellent expositions of Seiford and Thrall (1990) and Weyman-Jones (1991), which should be consulted for fuller details. The Farrell approach divides overall efficiency into two multiplicative components namely technical efficiency and allocative efficiency and provides definitions and a computational framework for both. Technical efficiency and allocative efficiency are defined in terms of a production frontier as the ratio of potential and actual performance. Figure 1 illustrates the concept introduced by Farrell. Suppose a firm produces an output of, Y , using two inputs X_1 and X_2 with production function of $Y= f(X_1,X_2)$. Assume for the moment that the production function exhibits constant returns to scale. This means that only one locus, the unit isoquant for Y=1 needs be drawn. Thus the production function may be written $Y = f(X_1/Y,X_2/Y) = 1$ so that the frontier technology can be characterised by the unit isoquant I I' in figure 1.

As shown in the diagram point E represents $(X_1/Y, X_2/Y)$. The ratio OF/OE measures the technical inefficiency of the firm. OF/OE is the ratio of inputs required to produce Y to the inputs actually consumed to produce Y, given the input mix used. The firm would be technically efficient if it produces one unit of output Y, using the input mix represented by F on the isoquant. That is the technical or productive efficiency of the firm is given by the ratio OF/OE < 1. If PP' represents the ratio of input prices, i.e. the isocost line, then the ratio OH/OF measures allocative efficiency. The firm would be allocatively or price efficient if it uses the input mix represented by G. The firm's allocative efficiency is OH/OF < 1. By operating at G, the firm would be on the isocost line that represents a fraction OH/OF, of total cost represented by isocost line through F. The overall efficiency of the firm which is the product of its price and technical efficiency ratios is measured by OH/OE = (OH/OF). (OF/OE).

Farrell suggested that the comparison of efficiency performance is made with the best actually achieved in the industry i.e. the observed industry standard. A best practice linear approximation to the isoquant is constructed from empirically observed input-output combinations of the firms in the industry. In other words the efficiency frontier is made of those firms which are efficient relative to other firms under evaluation. Efficiency computations are made relative to this frontier.

The frontier is convex to the origin and has a negative slope. Geometrically, the efficient frontier is formed by connecting points relating to efficient firms in the industry. A firm is efficient if no other firm or convex combination of firms lies on a ray between it and the origin. Firms on the frontier have an efficiency rating of unity while firms off the frontier which are inefficient have an efficiency rating of less than one. In terms of figure 2, firms at P1, P2 and P3 are efficient while firms at P4 and P7 are inefficient. Using Farrell methodology technical efficiency is measured by weighting two adjacent points P1 and P2 which give $P4 = \lambda_1 P1 + \lambda_2 P_2$,
$\lambda i \geq 0$. Thus P4 is inefficient in Figure 2 since $\lambda_1 + \lambda_2 > 1$ and its efficiency rating is
$(\lambda_1 + \lambda_2)^{-1}$.

2.2 Data Envelopment Analysis Model

Farrell's approach of computing the efficient frontier as a convex hull in the input coefficient space was generalised to multiple outputs by Charnes *et al* (1978). It was reformulated into calculating the individual input-saving efficiency measures by solving a Linear Programming problem for each unit under constant returns to scale assumptions and became known as Data Envelopment analysis. Fare *et al* (1983), Banker *et al* (1984), Brynes *et al* (1984) and Bjurek, Hjalmarsson and Forsund (1990) extended this approach to the case of variable returns to scale and developed corresponding efficiency measures.

DEA evaluates and identifies inefficiencies of firms or decision making units (DMUs), provides targets for improvement for inefficient DMUs and therefore serves as a planning aid to management. Technical inefficiencies are identified with failures to achieve best possible output levels and or usage of excessive amounts of inputs.

The DEA approach in a multi-inputs and multi-outputs model assumes that there are n firms and each firm ($j = 1,....,n$) consumes varying amounts of m inputs (X_{ij}, $i = 1,....,m$) to produce s different outputs (Y_{rj}, $r = 1,....,s$). The model also assumes that $X_{ji} \geq 0$ and $Y_{jr} \geq 0$. Charnes *et al* (1978) use the ratio of weighted outputs to inputs, with output weights U_r and input weights V_i as a measure of efficiency where the ratio for the particular firm being evaluated is maximised. This is subject to constraints that the corresponding ratio for each unit including the one under evaluation does not exceed 1. This ratio forms the objective function for the j_oth unit being evaluated. Technical efficiency can be calculated by solving a fractional programming problem and symbolically can be expressed as:

$$\max h_o(U,V) = \sum_{r=1} U_r Y_{r,jo} / \sum_{i=1} V_i X_{i,jo} \quad (1)$$

subject to

$$\sum_{r=1} U_r Y_{rj} / \sum_{i=1} V_i X_{ij} \leq 1 \quad (j=1,....jo,....n)$$

$$U_r \geq 0 \qquad (r=1,......,s)$$

$$V_i \geq 0 \qquad (i=1,......,m)$$

The above fractional linear program is both non-linear and non-convex and therefore is not used for actual computation of the DEA efficiency score (Charnes, Coopers and Rhodes (CCR), 1978). However CCR showed that the problem is capable of solution by linear programming methods. In the output augmentation approach a set of weights is selected which maximises output subject to the restriction that the weighted sum of the inputs is constrained to be unity. An alternative approach, the input conservation method, will not be discussed here since adequate accounts exist in the literature. (Seiford and Thrall, 1990).

The output maximisation approach can be determined as follows:

$$\text{Max } \{\sum_{r=1} U_r Y_{r,jo}\} \tag{2}$$

subject to

$$0 \geq \sum_{r=1} U_r Y_{rj} - \sum_{i=1} V_i X_{ij} \quad (j=1,\ldots,j_o\ldots,n)$$

$$1 = \sum_{i=1} V_i Xi_{,jo}$$

$$V_i, U_r \geq 0 \quad (i=1,\ldots..,m)$$
$$(r=1,\ldots..,s)$$

Note that in this problem, the Us and the Vs are the variables while the Ys and Xs are observed data and are therefore treated as constants. Note further that the problem has potentially many variables but only two constraints and therefore it is convenient to convert it into its dual form for solution. In addition to computational convenience, the dual interestingly yields a relative efficiency index for each of the decision making units (observations) in the data set (Ganley and Cubbins, 1992). The linear programming problem in model (2) can be presented as a dual problem as follows:

$$\text{Min } \theta$$

Subject to

$$\sum_{j=1} X_{ij}\lambda_j \leq \theta X_{io} \tag{3}$$

$$\sum_{j=1} Y_{rj}\lambda_j \geq Y_{ro}$$

$$\lambda_j \geq 0$$

Bjurek, Hjalmarsson and Forsund, (1990) showed that depending on the assumption about the scale properties of the production set three different input-saving measures may be derived. The first measure DEAC, is calculated under the assumption of constant return to scale. No alteration to the dual program is needed to solve for constant returns to scale. The second efficiency measure, called DEAV by Bjurek and Hjalmarsson and Forsund, is calculated under the assumption of variable returns to scale. Implementation of this modified problem requires the addition of an extra constraint in the dual formulation, $\sum\lambda_j = 1$ (Fare, Grosskopf and Lovell, 1994). The third measure, DEAN is obtained under the assumption of non - increasing return to scale. Augmenting the constraints in the dual with $\sum\lambda_j \leq 1$ enables estimation of the non increasing returns model.

3 THE MALMQUIST INDEX AND PRODUCTIVITY GROWTH ANALYSIS

The DEA method can be used to compute a Malmquist index for measuring total productivity growth. A Malmquist index allows for the decomposition of productivity growth into two components namely technical change and efficiency change. This provides evidence concerning patterns of total productivity growth and indicates whether productivity growth is due to catching up with frontier units or to technical change (shifts in the frontier) over time. Hjalmarsson and Veiderpass (1992) define the Malmquist index as the ratio between Farrell measures for a production unit which for technical efficiency at two different points in time is measured relative to two different frontiers. Fare *et al* (1994) use the Malmquist index to measure total productivity change which is calculated as the geometric mean of two Malmquist indexes and decompose it into its two components the technical change and efficiency change.

When the production function is characterised by constant return to scale and input-saving technical efficiency coincides with the output increasing technical efficiency, the Malmquist index at time t, M_t, with frontier F_t as a reference base is defined as

$$M_t = E_{t,t+1}/E_{t,t}$$

where

$E_{t,t+1}$ is the technical efficiency of P at time t+1 relative to F_t

$E_{t,t}$ is the technical efficiency of P at time t relative to frontier F_t

The Malmquist index at time t+1, M_{t+1}, with frontier F_{t+1} as a reference base is defined as

$$M_{t+1} = E_{t+1,t+1}/E_{t+1,t}$$

where

$E_{t+1,t+1}$ is the technical efficiency of P in year t+1 relative to F_{t+1}

$E_{t+1,t}$ is the technical efficiency of P in year t+1 measured against F_1

The Malmquist productivity change index defined as the geometric mean of two Malmquist indexes can be expressed as :

$$MG = \{M_t \times M_{t+1}\}^{½}$$

$$= [\{E_{t,t+1}/E_{t,t}\} \times \{E_{t+1,t+1}/E_{t+1,t}\}]^{½}$$

Following Hjalmarsson and Veiderpass(1992) an equivalent way of writing this index is:

$$MG = \{E_{t,t+1}/E_{t,t}\} \times [\{E_{t,t+1}/E_{t+1,t+1}\}\{E_{t,t}/E_{t+1,t}\}]^{½}$$

where the ratio $E_{t,t+1}/E_{t,t}$ measures the change in relative efficiency between year t and year t+1. The term $[\{E_{t,t+1}/E_{t+1,t+1}\}\{E_{t,t}/E_{t+1,t}\}]^{½}$ represents the shift in technology due to technical change or innovation.

The ratios in the first bracket measures the relative technical efficiency of a unit at time t and t+1 reflecting changes in relative efficiency over time. The ratios in the second bracket measure shifts in frontier technology at output levels Y_t and Y_{t+1} respectively. A Malmquist index greater than one indicates an improvement in productivity while less than one is associated with declining performance over time. Although the product of the efficiency change and the technical change is equal to the Malmquist productivity index, the two components may be moving in the opposite directions.

3.1 Estimation of Malmquist Productivity Index using linear programming approach

The above Malmquist productivity indexes have been calculated using the mathematical programming model of the frontier production function by a number of authors including Price and Weyman-Jones (1993).

To compute the above efficiency indices the following linear programming problems are solved (for the choice of variables q, $l_1 .... l_n$) for each firm taken in turn:

The relative efficiency of the firm at time p relative to the efficiency frontier at time q is:

$$\text{Min } q_{p,q}$$

$$\text{s.t } X_q \lambda_q - q_p X_{op} \leq 0$$

$$Y_q \lambda_q \geq Y_{op}$$

$$\lambda_q \geq 0$$

$$p,q = t,t+1$$

Substituting p = q = t, in the above optimisation problem yields an efficiency value for firms in period t relative to the period t frontier, $q_{t,t}$. The relative efficiency of a firm in period t+1 compared to the t+1 frontier, $q_{t+1,t+1}$, is calculated by setting p = q = t+1. Doing this permits the calculation of the efficiency of a firm in period t relative to the period t+1 frontier, $q_{t,t+1}$. Finally, when p = t+1 and q = t we can find the efficiency of a firm in t+1 relative to the frontier at t, $q_{t+1,t}$.

The Malmquist index of productivity change after year t, MG, can then be decomposed into a catching up effect, MC and a frontier shift effect MF ,

$$MC = q_{t+1,t+1} / q_{t,t}$$

$$MF_i = [\{q_{t,t+1}/ q_{t+1,t+1}\}\{ q_{t,t}/ q_{t+1,t}\}]^{1/2}$$

where

$q_{t+1,t+1} / q_{t,t}$ is the productivity growth due to catching up effect and $[\{q_{t,t+1}/ q_{t+1,t+1}\}\{ q_{t,t}/ q_{t+1,t}\}]^{1/2}$ is the productivity growth due to technological change or frontier change

4 EFFICIENCY IN ELECTRICITY PRODUCTION - THE EMPIRICAL EVIDENCE

This section employs the DEA methodology based on output augmentation to calculate the technical or productive efficiencies of the National Electricity Board by using two approaches. The first approach uses cross section data to estimate NEB's efficiency in comparison to the relative efficiency of 27 other electricity producers in different countries in 1987. Data used are from a unique series published by the World Bank (Escay, 1990)[3]. The second approach uses time series data from 1975 to 1990 to compare the relative technical efficiency of the NEB with EGAT - the Electricity Generating Authority in Thailand - and with the CEGB in the United Kingdom. Data for NEB and CEGB are gathered from annual financial and statistical reports while data for EGAT are provided by COPED discussion paper series[4].

4.1 Efficiency comparisons using cross-sectional data

The cross section data used in the analysis comprises information on a sample of 27 electricity utilities in developing countries for 1987. We attempt to secure homogeneity by selecting only countries in a specific income range, i.e.countries with GDP per capita in the region of US$1500-$2800. The model adopts the input minimisation approach and assumes four input (X) variables and one output variable as below:

Inputs :

X1 = Installed capacity (MW)

X2 = Labour

X3 = Total system losses (%)

X4 = Generation capacity factor (%)

Output :

Y1 = Gross electricity produced (GWh)

Installed capacity is included as an input on the grounds that in developing countries it is likely to constitute an effective constraint on output. The assumption is less justified for mature systems such as the CEGB. Labour includes all employees in the electricity sector and ideally should be split between various functions. Unfortunately such detailed information was not available . The Generating capacity factor variable provides information on intensity of use of the capital equipment. System losses help to account for the effects of significantly different standards of maintenance and operation of different systems.

As pointed out by Weyman-Jones (1991) the advantage of keeping the number of inputs (X) and outputs (Y) small relative to the number of firms (N) is that as the ratio of (Y+S)/N rises the ability of the DEA to discriminate amongst firm falls significantly, since it becomes more likely that any given firm will find some set of output and input weights which will make it appear efficient.

Using the data as provided from Appendix 1, the constants in the linear programs are the Xs and Ys where

$X_{11} \ldots X_{127}$ = Installed capacity of Country 1 (C1:Algeria) to Country 27 (C27:Zimbabwe)

$X_{21}.....X_{227}$ = Labour of C1.....C27

$X_{31}.....X_{327}$ = Total system losses of C1......C27

$X_{41}.....X_{427}$ = Generation capacity factor C1.....C27

$Y_{11}.....Y_{127}$ = Gross electricity produced by C1....C27

Although various special purpose DEA programs exist, the linear programming basis is not always evident or its special features utilised. Some are 'black boxish' and allow the user only a restricted range of options. Other researchers have developed routines to work with commercial LP programs, but these tend to require access to large mainframe computing systems and software. We developed our own software, Lambda, designed to be used with the freely available LP_SOLVE linear programming system (Berkelaar, 1994). This determines the efficiency performance of each firm as a proportion of that of the 'nearest' efficient producer/s. (Hawdon and McQueen, 1996).

The program is solved for each country with all other country data forming the reference set of potential best practice producers. As an example, the linear program for country 1 is set up as:

Min: θ

subject to

$3{,}836\lambda_1 + 16{,}593\lambda_2 + ...+ 2{,}071\lambda_{27} - 3{,}836\theta \leq 0$

$$18{,}800\lambda_1 + 34{,}480\lambda_2 + \ldots\ldots + 4{,}325\lambda_{27} - 18{,}800\theta \leq 0$$

$$15\lambda_1 + 17\lambda_2 + \ldots\ldots + 10\lambda_{27} - 15\theta \leq 0$$

$$40\lambda_1 + 37\lambda_2 + \ldots\ldots + 39\lambda_{27} - 40\theta \leq 0$$

$$13{,}400\ \lambda_1 + 52{,}165\ \lambda_2 + \ldots\ldots + 7{,}008\ \lambda_{27} \geq 13{,}400$$

Table 1 sets out the efficiency measures computed from the LP solution.

It can be seen that the technical efficiency of the electricity sector in different countries varies widely with relative ratings running from 48 percent to 100 percent. Electricity sectors in Chile, Columbia, Egypt, Korea, China, Brazil and former Yugoslavia achieved the highest scores and form the reference frontier or reference technology.

Malaysia with an efficiency of approximately 70% ranked 18th in the sample, somewhat behind Thailand. Two countries, Egypt and Yugoslavia, form the reference set for both Malaysia and Thailand. Thus if Malaysia wishes to move towards the efficient frontier for developing countries, it might be advised to adopt a weighted combination of the technologies of these countries producers'. It should be emphasised that this advice depends on the reliability of the sample: the countries might be even better advised to leapfrog over the

Table 1: Electricity sector efficiency of selected LDCs by using DEA method - 1987

Country (DMUs)	Objective Function θ CS	Reference Frontier Constant Returns to Scale (C9)	(C11)	(C13)	(C14)	(C15)	(C16)	(C17)	Objective Function θ Variable Returns - VS
1. Chile (C14)	1.0000	-	-	1.0000	-	-	-	-	1.0000
2. Columbia (C16)	1.0000	-	-	-	-	-	1.0000	-	1.0000
3. Egypt (C17)	1.0000	-	-	-	-	-	-	1.0000	1.0000
4. Korea (C11)	1.0000	-	1.0000	-	-	-	-	-	1.0000
5. China (C15	1.0000	-	-	-	-	-	-	-	1.0000
6. Brazil (C13)	1.0000	-	-	1.0000	-	-	-	-	1.0000
7. Yugoslavia (C9)	0.9951	0.9951	-	-	-	-	-	-	1.0000
8. Mexico (C19)	0.9212	0.3651	0.1193	0.3446	-	-	-	-	0.9423
9. Hungary (C3)	0.8797	0.0911	-	-	-	-	-	0.6873	0.9334
10. Venezuela (C25)	0.6244	-	0.5786	0.0185	-	-	-	-	1.0000
11. Ghana (C18)	0.7926	0.0391	-	-	-	-	0.0435	-	1.0000
12. Peru (C21)	0.7681	0.1662	-	-	-	-	-	0.0238	0.8672
13. Romania (C23)	0.7654	0.4553	-	0.1066	-	0.0297	-	-	1.0000
14. Thailand (C7)	0.7600	0.2090	-	-	-	-	-	0.4035	0.9410
15. Argentina (C2)	0.7515	0.1798	0.3414	0.0507	-	-	-	-	0.9315
16. Zimbabwe (C27)	0.7451	-	-	-	0.0991	-	0.0846	-	1.0000
17. Turkey (C24)	0.7165	0.5057	-	0.0059	-	0.0047	-	-	0.9250
18. Malaysia (C4)	0.7042	0.0531	-	-	-	-	-	0.3664	0.8803
19. Algeria (C1)	0.6777	0.0289	-	-	-	-	-	0.4049	0.9321
20. Indonesia (C10)	0.6720	0.4093	-	-	-	-	-	0.0035	0.9503
21. Panama (C5)	0.6246	-	-	-	-	-	-	0.6246	1.0000
22. Portugal (C22)	0.6237	0.0989	0.0461	-	-	-	0.2376	-	1.0000
23. Uruguay (C8)	0.6231	-	-	-	-	-	-	0.1385	0.9714
24. Bangladesh (C12)	0.6019	-	-	-	-	-	-	0.1815	0.9413
25. Nigeria (C20)	0.4863	0.0486	-	-	-	-	-	0.1839	1.0000
26. Zaire (C26)	0.4850	-	0.0094	-	0.0991	-	0.0846	-	0.9000
27. Syria (C6)	0.4813	-	-		-	-	-	0.2215	1.0000

reference set to attainable technologies in non developing countries which enjoy greater economies of scale for example.

The efficiency of the Malaysian electricity sector relative to that of some of the other electricity utilities is illustrated in Figure 3. There are two characteristics common to all the utilities which form the reference frontier. One, all the six utilities have a high capacity factor ranging from 44 percent to 59 percent. This suggests elimination of wasteful investment as a factor for efficiency improvements. Mexico's capacity factor was also within the same region as those on the reference frontier and it had a high efficiency index (92.1%). Second, all utilities which formed the reference frontier, with the exception of Korea and China, have a high percentage of hydro power capacity of between 42.6 percent and 84.9 percent. In the case of Korea, a low hydro power capacity is compensated by significant usage of nuclear power amounting to 27 percent of the installed capacity. To the extent that hydro power provides base load in all systems, the greater the percentage of base load supplied by the generator the more technically efficient it is seen to be.

To what extent are the results affected by economies of scale in electricity production? Two tests were carried out to determine the impact of size of output on efficiency - a non increasing returns to scale (NIS) analysis and a variable returns to scale (VS) analysis. The

NIS analysis produced identical results to those obtained under the original assumption of constant returns (CS) indicating that either CS or increasing returns prevailed throughout the sample. The VS analysis, reported in Table 1, suggests that many of the small scale producers could be inefficient simply because of size. This result applies to Nigeria, Syria, Zimbabwe, Ghana and Panama whose efficiencies ranged between .48 and .75 in the CS analysis. Very large scale producers like China and Brazil are confirmed as efficient under both assumptions, indicating that size is indeed important. In order to correct for a possible distortion introduced by the presence of such countries, those with output above 70,000 Gwh were excluded. Interestingly the graph of efficiency for the remaining countries, figure 4, strongly suggests a mid range of relatively efficient scale between 29,000 and 35,000 Gwh where 3 out of 5 countries scored 1 and the average efficiency was .86. Countries in this range were Hungary, Thailand, Egypt, Colombia and Indonesia, although Indonesia scored relatively less well than the others. Thus while overall economies of scale were present for the largest electricity producers, the evidence suggests the existence of local optima for medium size operators similar to Malaysia. Malaysia's performance is thus not entirely explained by lack of scale economies in its electricity generation sector.

4.2 Efficiency comparisons using DEA method between NEB EGAT and CEGB from 1975-1990

The analysis so far leaves open the question of whether Malaysia's relative inefficiency in electricity production was part of a long term process or merely a peculiarity of a particular period. Although time series data is not available for all countries in the sample, it was possible to obtain unique information on two countries' producers - Malaysia's NEB and Thailand's EGAT - which would permit an analysis of changing efficiencies over time. Comparable data on the UK CEGB enables a rigorous comparison with best practise available at the time.

The production model again consists of one output, electricity generated, and four inputs. Of the four inputs, one, the capacity factor is replaced by thermal efficiency because of lack of data. There is likely however to be some positive correlation between capacity factor which measures intensity of use of equipment and thermal efficiency, so that this alteration may not have much effect on the investigation.

The output augmentation model is as follows:

Inputs:

X_1 = Installed capacity (MW) / Capital

X_2 = Labour

X_3 = Electricity losses (%)

X_4 = Thermal efficiency (%)

Output

Y_1 = Electricity generated (GWh)

The DEA analysis is repeated each year between 1975 and 1990 using the three countries in each run. In any one year two out of the three will appear to be efficient. Thus the interest lies in the switch between efficiency and inefficiency. Given that the CEGB system is much larger that that of either of the other countries, and that economies of scale have been established in the previous analysis, we would expect a vivid contrast between the two developing countries systems to emerge.

Table 2: Results of efficiency comparisons using DEA method 1975-1990

YEAR	NEB (C1)			EGAT (C2)			CEGB (C3)		
	θ	C2	C3	θ	C1	C3	θ	C1	C2
1975	1.0000	-	-	0.8918	0.7567	0.0218	1.0000	-	-
1976	1.0000	-	-	0.9938	0.9146	0.0216	1.0000	-	-
1977	1.0000	-	-	0.9331	0.7324	0.0265	1.0000	-	-
1978	0.9254	0.4036	0.0083	1.0000	-	-	1.0000	-	-
1979	0.9731	0.4350	0.0106	1.0000	-	-	1.0000	-	-
1980	1.0000	-	-	1.0000	-	-	1.0000	-	-
1981	1.0000	-	-	0.9548	0.9388	0.0267	1.0000	-	-
1982	1.0000	-	-	1.0000	-	-	1.0000	-	-
1983	1.0000	-	-	0.9895	0.8949	0.0430	1.0000	-	-
1984	0.9176	-	0.0607	0.9234	-	0.0981	1.0000	-	-
1985	0.7630	-	0.0614	0.8793	-	0.1009	1.0000	-	-
1986	0.8596	-	0.0658	0.9481	-	0.1097	1.0000	-	-
1987	0.8488	0.2457	0.0378	1.0000	-	-	1.0000	-	-
1988	0.8552	0.2500	0.0431	1.0000	-	-	1.0000	-	-
1989	1.0000	-	-	1.0000	-	-	1.0000	-	-
1990	1.0000	-	-	1.0000	-	-	1.0000	-	-

Note: Each row contains efficiencies, θ, and reference set weights.

The results indicate that EGAT has usually been more efficient than NEB. Throughout the 1975-1990 period the CEGB was indeed the most efficient of the three producers and has consistently appeared on the reference frontier curve. The following observations can be made on the efficiency trend of NEB and EGAT.

i. With the exception of 1978 and 1979, NEB was relatively more efficient than EGAT in the early years from 1975 until 1983 - NEB was operating on the reference frontier curve. Its efficiency dropped in 1978 and recovered somewhat in 1979 during which EGAT reached the efficient frontier. This development could be attributable to three factors. Firstly, there was rapid expansion of installed capacity at a time of relatively low demand growth. Installed capacity grew by 24.3 percent and 14.0 percent in 1978 and 1979 respectively, against 8.1 percent and 11.0 percent growth of demand. This helps to explain NEB's high excess capacity during this period. Secondly, the thermal efficiency of EGAT increased to 34.1 percent in 1978 from 33.8 percent the previous year while the thermal efficiency of NEB remained unchanged at 29.6 percent. The thermal efficiency of NEB declined during the following year by 2.7 percent to 28.8 as compared to a decline by 1.5 percent to 33.6 percent of EGAT.

ii. EGAT was more efficient than NEB, but did not lie on the reference frontier curve, from 1984 to 1986. There was high excess capacity during this period reflected in NEB's high reserved capacity of between 42 to 52 percent. In 1985 installed capacity grew by about 24 percent, increasing reserved capacity to 52 percent. The completion of combined cycle plants in Paka Trengganu certainly contributed to about 25 percent of the total installed capacity. During the same period EGAT improved its thermal efficiency by the introduction of combined cycle plant in the period (Dang, 1991))

iii. By 1989, NEB managed to improve its efficiency significantly, and both NEB and EGAT were on the reference frontier in 1989 and 1990. This is attributable to two factors. Firstly, there was less reserve capacity for NEB as a result of a marked slowdown in capacity expansion. Secondly, NEB had diversified its mix of energy plant types with the completion of a major gas pipe line and combined cycle plant in the period since 1987. NEB's thermal efficiency reached its highest level of 36.4 percent in 1990. By the 1990/1991 financial year, generation capacity comprised 43 percent of steam, 22.2 percent of hydro, 15.5 percent of combined cycle, 18.6 percent of open cycle gas turbine and 0.7 percent diesel engine. In addition most of the oil fired stations have been converted to dual firing capability of gas and oil.[5]

On average, during the 1975-1990 period, NEB was slightly less efficient than EGAT. EGAT was operating at a higher thermal plant efficiency at an average level of 36 percent as compared to 31.3 percent for the NEB. In addition EGAT had lower system losses (15.3 percent) than NEB (13.9 percent). The main problem with NEB was a greater dependence on auxiliary power, around 21 percent higher than that of EGAT. In terms of transmission and distribution losses on average NEB was also slightly less efficient than EGAT.

5 NEB'S PRODUCTIVITY GROWTH

Table 3 shows the Malmquist productivity index of the NEB from 1976-1990. The objective of this measurement is to trace NEB's productivity growth over a period of time. Recall that, if the value of the Malmquist index or any of its components is less than 1, it denotes deterioration in performance. Values greater than 1 denote improvements in relative performance. On average, productivity improvement due to catching up (1.0208) is higher than improvement due to technological shift (0.9826). The productivity growth due to technological shift is not accompanied by catching up effect productivity improvement. Thus there is no overall productivity growth in the period and this is indicated by a mean index value of 1. By implication, therefore, in order for NEB to achieve productivity growth, besides investing in new technology, it must improve its operational efficiency. This includes increased productivity of labour which is a central issue in the privatisation programme of the NEB.

Table 3: NEB's Malmquist Productivity Index (1975-1990)

Year	MF	MC	MPI
1976	0.9469	1.0561	1.0000
1977	0.9999	1.0001	0.9999
1978	1.0000	1.0000	1.0000
1979	1.0000	1.0000	1.0000
1980	1.0001	0.9999	0.9999
1981	1.0000	1.0000	1.0000
1982	0.9999	1.0001	1.0000
1983	1.0001	1.0000	1.0001
1984	1.0001	1.0000	1.0000
1985	0.9297	1.0758	1.0001
1986	0.9999	1.0001	1.0000
1987	0.9669	1.0343	1.0003
1988	0.9669	1.0343	1.0001
1989	0.8987	1.1128	1.0001
1990	0.9999	0.9992	0.9991
Mean	0.9826	1.0208	1.0000

Note: MPI - Malmquist Productivity Index

MF - Frontier shift effect

MC - Catching up effec

6 CONCLUSIONS

This study has examined the efficiency of Malaysia's NEB relative to 27 other electricity utilities in other developing countries in 1987 using the DEA approach. Results show that the NEB, although operating around mean technical efficiency fell far short of best practice. It ranked 18th out of the 27 countries in terms of relative technical efficiency. Comparisons based on time series data from 1975-1990 between NEB, EGAT and CEGB also confirm that on the average NEB was relatively less efficient in electricity generation. The reasons for the relatively poor performance of NEB are concerned with its high excess capacity and low thermal efficiency as compared to EGAT. Failure to complete power projects as planned led to further variability in performance. However, both the high growth in demand for electricity and the increase in thermal efficiency have allowed NEB to improve its relative position during limited periods. In spite of this, there was no overall productivity growth from 1975 to 1990.

Two important conclusions emerge from the study. Firstly, the DEA analysis indicates that there are immediate benefits to Malaysia to be achieved from continued improvements in the technical efficiency of electricity production. Adopting the reference frontier could reduce costs by 30% in 1987 prices. Such improvements could be used as one criteria for evaluating the success of the current privatisation programme. Secondly, these potential efficiency gains ignore the important dynamic impact of competition on the electricity sector. The example of the UK suggests that introducing competition as well as privatisation can open the door to ongoing efficiency gains.

REFERENCES

Banker, R., Cooper, W. (1984). *Some Models for Estimating Technical and Scale Efficiencies*. Management Science, 1078-1092

Berkelaar, M.R.C. (1994) *LP_SOLVE Manual*, University of Eindhoven, Holland.

Brynes, P., Fare, R.,Grosskopf, S. *Measuring Productive Efficiency: An Application to Illinois Strip Mines*. Management Science, 30, 671-678.

Bjurek, H., Hjalmarsson, L., Forsund, F.R. (1990)*Deterministic Parametric and Nonparametric estimation of Efficiency in service Production*. Scandinavian Journal of Economics, 213-217.

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

Charnes, A., Cooper,W.W., Lewin, A.Y., Morey, R.C., and Rousseau, J. (1985) *Sensitivity and stability analysis in DEA*. Annals of Operations Research 2, 139-156

Cowing, T, Stevenson, R. (1981) *Productivity Measurement in Regulated Industries*. Academic Press.

Dang, G.V. (1991) *Electricity System Performance in South East Asia. Cooperative Programme on Energy and Development*. (COPED) and Asia Institute of Technology.

Dang, G.V., Lim, C.J.V.Jnr (1990) *Key issues facing the electricity system of Thailand* Asia Institute of Technology.

Escay, J.R. (1990) *Summary Power Sheets of 1987 Power and Commercial Energy Statistics for 100 Developing Countries*. IENED, Washington, The World Bank.

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

Fare, R Grosskopf, S., Norris, M, Zhang, Z. (1994) *Productivity Growth Technological Progress , and Efficiency Change in Industrialised Countries*. American Economic Review March 1994, 84, 1, 66-83.

Fare, R., Grosskopf, S., and Lovell, C. A. K. (1994) *Production Frontiers*. Cambridge University Press.

Farrell, M.J. *The Measurement of Productive Efficiency*. Journal of the Royal Statistical Society, Series A, General, 120(3) 253-281.

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

Hawdon, D. and McQueen, I. (1996) *Using Lambda for DEA*. SEEDS TP961 Department of Economics, University of Surrey.

Hjalmarsson, L. Veiderpass, A. (1992) *Productivity in Swedish Electricity Retail Distribution*. Scandinavian Journal of Economics

Price, C. Weyman-Jones, T. Malmquist *Indices of Productivity Change in the UK Gas Industry Before and After Privatisation*. Economics Research Paper No 93/12, Department of Economics, Loughborough University of Technology.

Seiford, L.M. and Thrall, R.M. (1990) *Recent developments in DEA*. Journal of Econometrics, 46, 39-56.

Weyman-Jones, G.T. (1991) *Productive Efficiency in Regulated Industry: The Area Electricity Boards of England and Wales,* Energy Economics, 3, p116-122

The World Bank (1993) *The World Bank's role in the electric power sector: policies for effective institutional, regulatory and financial reform.* Washington, The World Bank

NOTES

1. Since it was developed by Charnes et al (1978) more than 400 articles have been written on DEA. (Seiford, Thrall, 1990)

2. The major limitation of the DEA method lies in its treatment of uncertainty. To the extent that there are errors of measurement, there will be uncertainty surrounding the efficiency calculations. Some progress has been made towards introducing uncertainty into DEA models, but as yet no generally agreed method exist regarding its treatment.

3. The information was gathered by members of the Energy Development Division of the World Bank's Industry and Energy Department (IENED) and 'energy staff in operations'. It is a compilation of published statistics and internal World Bank data sources on 100 developing countries.

4. See Dang (1991) and Dang and Lim (1990).

5. See "Privatisation of Tenaga Nasional Berhad". A seminar paper on Malaysian securities Market in Tokyo on 29.11.1991.

Figure1: Technical and Allocative Efficiency

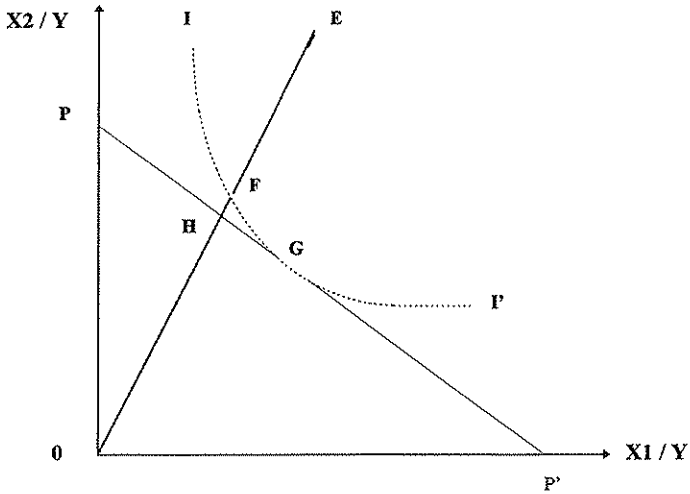


Figure 2: Isoquant Frontier

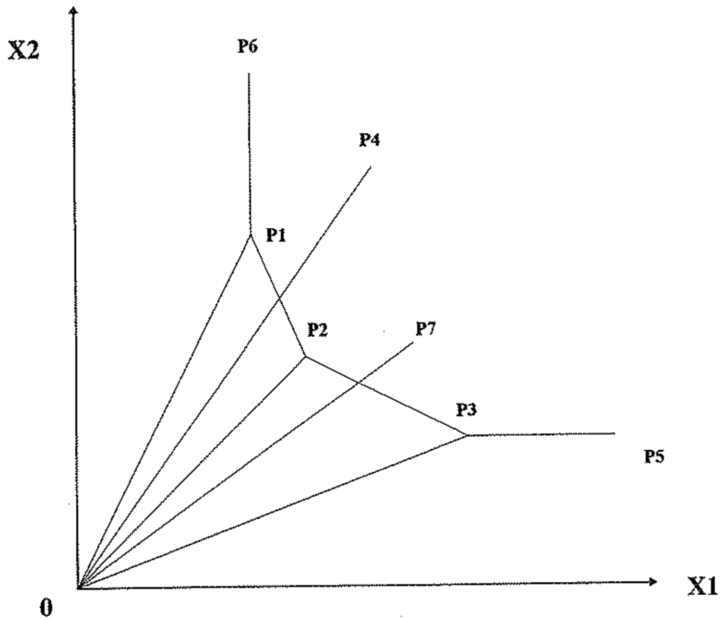
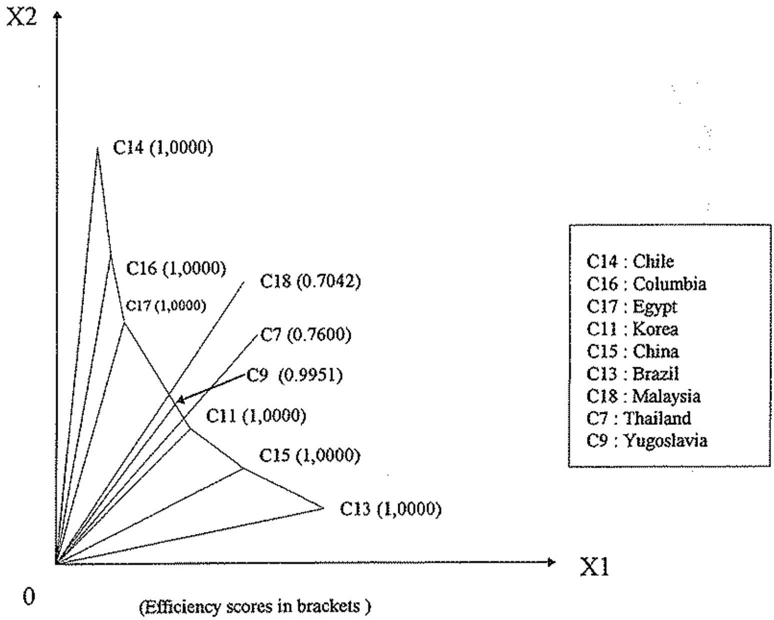


Figure 3: DEA Reference Frontier



(Efficiency scores in brackets)

Figure 4: Efficiency and Scale

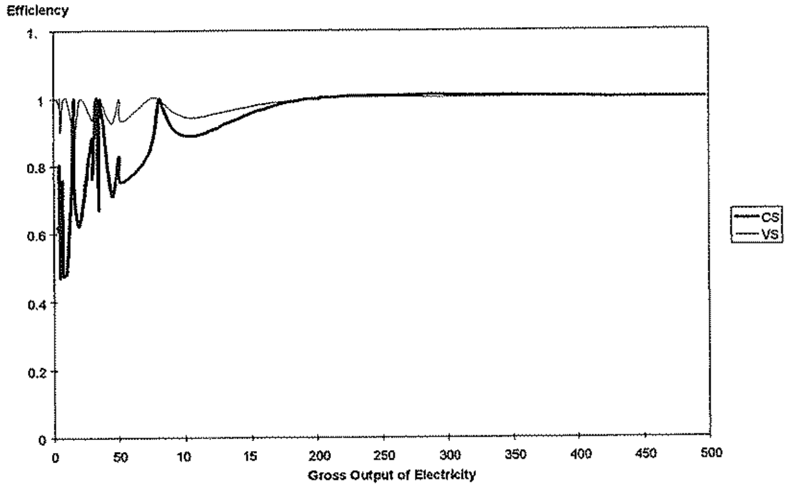
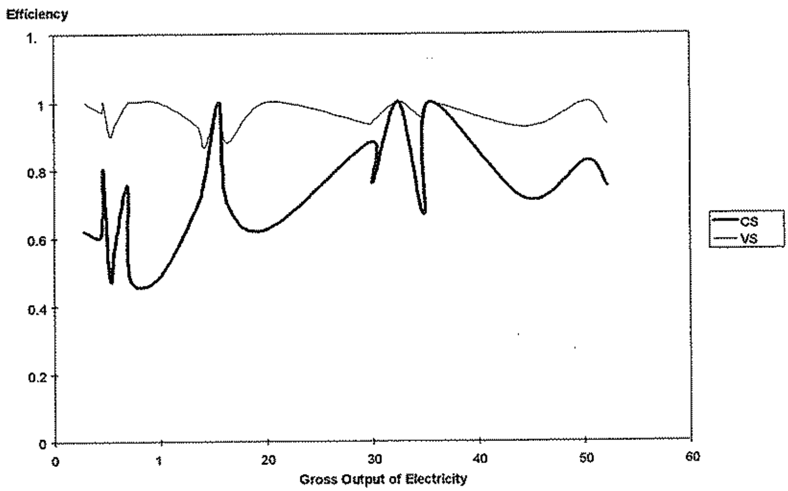


Figure 5: Efficiency and Scale - Smaller Producers



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