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ECONOMIES OF SCALE IN THE  
NEW ZEALAND ELECTRICITY DISTRIBUTION INDUSTRY

DAVID E. A. GILES and NICOLAS S. WYATT

*Discussion Paper*

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**June 1989**

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NEW ZEALAND ELECTRICITY DISTRIBUTION INDUSTRY\***

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\*This paper is circulated for discussion and comments. It should not be quoted without the prior approval of the author.

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## I. Introduction

The New Zealand electricity industry is currently undergoing a process of deregulation, and there is considerable interest in its future structure. This industry is divided into three horizontal layers, dealing with the generation, high voltage transmission, and final distribution of electricity. Although a few distributors generate a significant proportion of their requirements, there has been no trend towards vertical integration. Generation and transmission are currently under the control of the Electricity Corporation of New Zealand (ECNZ), from whom the various regional Electricity Supply Authorities (ESAs) purchase bulk electricity, and transmit it from ECNZ's substations to the end users.<sup>1</sup> This study focuses on these ESAs and examines whether there are economies of scale in the distribution of electricity in New Zealand.

At the time of our sample there were 60 ESAs in New Zealand,<sup>2</sup> a mountainous country comprising two principal islands, with a population of approximately 3.3 million people. Some 70% of the population live in the North Island (44,281 sq. miles), the Auckland metropolitan area accounting for 840,000 people, while in the South Island (58,093 sq miles) the largest urban centre is Christchurch (population 300,000). Constitutionally, the ESAs are of two types - Electric Power Boards (EPBs), which are independent statutory bodies run by boards elected from the area over which the ESA has a franchise; and the Municipal Electricity Departments (MEDs), which are the trading arms of territorial local government and are managed by committees of the relevant local council. Each ESA has an area franchise and an associated obligation to supply

electricity at the lowest possible price. Only licensed firms may distribute electricity. Strictly, these franchises do not exclude the operation of competitors, but in practice only one franchise has been issued for each area.

Debate over the scale of electricity distributors in New Zealand has raged for years. The geographical features of the country are unusually relevant, but given the number of consumers and the relatively small annual output (19,444 GWh in 1986/87), it is not surprising that the appropriateness of 60 or so ESAs has been questioned. A Royal Commission headed by Stanton (1959) concluded that the (then 83) ESAs were technically efficient, but would be improved by amalgamations. Twenty-six supply areas were recommended, but without explicit reference to (economic) scale economies. The latter were explored to some extent by Jones (1987) and with respect to the Christchurch region by McCutcheon et al. (1987). None of these studies employs any formal econometric analysis.

Several technical and organisational factors influence economies of scale in electricity distribution. Organisational economies may arise at the firm level as a result of staff specialisation and staff control costs. Below some size a firm may not be able to employ the optimal resources, while beyond some other size the firm faces increasing costs in controlling these resources. Organisational economies can arise from increasing the specialisation of managerial staff - the benefits of a larger firm depend on the gains from having this expertise "in house" in terms of cost and firm-specific knowledge gained. Conversely, organisational diseconomies may develop beyond a certain firm size,

perhaps because of increasing communication problems, the difficulty of maintaining consistent objectives, and the potential for managerial "slack".

The principal technical economies are in distribution equipment, which lead to economies of density, economies in capacity expansion and economies in the provision of capacity to meet peak requirements. An increase in equipment capacity leads to a less than proportionate rise in equipment cost. Larger capacity equipment also yields lower system costs as higher voltage operation lowers system energy losses. These factors contribute to economies of density. As the number of customers, and energy demand, rises for a given area, average cost falls. Supply security can also be improved when density rises. Several low voltage networks can be interconnected with open switches to provide different flow paths, so that a fault that might otherwise cut off supply can be bypassed. Such benefits are exhausted at a certain scale of operation by the requirement to keep separate the networks supplied by each ECNZ substation. All of this points to the potential for scale economies in this industry - the extent to which such economies are in fact present or are exhausted is, of course, an empirical issue.

Econometric studies of scale economies in electricity industries in other countries focus primarily on generation rather than distribution, and reflect the vertically integrated nature of this industry elsewhere (e.g., see Christensen and Greene (1976), Betancourt and Edwards (1987), and Sing (1987)). Other relevant studies include those of Neuberg (1977), Huettner and Landon (1978), Aivazian et al. (1987) and some of the material discussed

by Weiss (1975). A typical finding is that the average cost curves exhibit extensive "flat" regions - i.e. there is a wide range of outputs consistent with essentially constant returns to scale.

In this paper we use a Translog cost model and cross-section data for the 1986/87 financial year to estimate economies of scale in the distribution of electricity in New Zealand. The ESAs have a statutory obligation to supply electricity and are price takers in the purchase of bulk electricity from ECNZ (this being their major operating cost). An econometric model of cost, rather than production, is appropriate given that the firms are cost minimizers rather than profit maximisers<sup>3</sup>. The model and data used are described in the next two sections. Section IV discusses the results; and our conclusions are given in Section V.

## II. The Model

Costs for the firms in this industry are of the form

$$C = f(Y, P, I) \quad (1)$$

where  $C$  denotes total cost,  $Y$  is output,  $P$  is a vector of  $n$  input prices, and  $I$  is a vector of  $m$  additional industry-specific variables. In formulating such a relationship it is assumed that output and input prices are exogenous, and that (for a given technology) firms adjust input levels so as to minimize costs of production. Given the comments at the end of the last section, and our use of cross-section data, such assumptions seem reasonable in this case. In common with other related studies, we use the Translog function (e.g., Christensen et al. (1971, 1973)) to

formalise (1):

$$\begin{aligned}
 \ln C = & \alpha_0 + \alpha_Y \ln Y + \frac{1}{2} \gamma_{YY} (\ln Y)^2 + \sum_{i=1}^n \gamma_{Yi} \ln Y \ln P_i \\
 & + \frac{1}{2} \sum_{i=1}^n \sum_{j=1}^n \gamma_{ij} \ln P_i \ln P_j + \sum_{i=1}^n \alpha_i \ln P_i + \sum_{k=1}^m \beta_k \ln I_k \\
 & + \frac{1}{2} \sum_{k=1}^m \sum_{g=1}^m \beta_{kg} \ln I_k \ln I_g + \sum_{k=1}^m \beta_{kY} \ln I_k \ln Y \\
 & + \sum_{k=1}^m \sum_{i=1}^n \theta_{ki} \ln I_k \ln P_i, \quad (2)
 \end{aligned}$$

where  $\gamma_{ij} = \gamma_{ji}$  and  $\beta_{kg} = \beta_{gk}$ . The attractions of this functional form are that it is flexible enough to represent quite general production structures; it imposes no restrictions on factor substitutability; and it allows economies of scale to vary with output. To ensure that (2) is consistent with a well-behaved production function, it must be homogeneous of degree one in input prices, which implies :

$$\sum_{j=1}^n \gamma_{ij} = \sum_{i=1}^n \sum_{j=1}^n \gamma_{ij} = \sum_{i=1}^n \gamma_{ij} = 0$$

$$\sum_{i=1}^n \gamma_{Yi} = 0$$

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

$$\sum_{i=1}^n \theta_{ki} = 0 \quad ; \quad k = 1. \dots, m.$$

If  $X_i$  is the quantity of input  $i$ , applying Shephard's Lemma, the associated input cost share equations are :

$$S_i = (P_i X_i / C) = \alpha_i + \gamma_{yi} \ln Y + \sum_{j=1}^n \gamma_{ij} \ln P_j + \sum_{k=1}^m \theta_{ki} \ln I_k \quad (3)$$

(i = 1, ..., n)

Adding normally distributed error terms, our full model comprises equation (2) and the equations (3). The model is estimated by joint Maximum Likelihood (ML), with all of the mentioned parameter restrictions imposed. The well known singularity of the contemporaneous error covariance matrix associated with such allocation models is allowed for in the usual way - one of the share equations is dropped from the system, the coefficient estimates being invariant to the choice of this equation. Our primary interest is the measurement of scale economies. As is conventional, such economies are defined in terms of the relationship between cost and output along the expansion path. That is, with fixed input prices (and industry - specific variables) and costs minimized at each output level. Specifically, we define them as the ratio of average to marginal costs :

$$SCALE \equiv (\partial \ln C / \partial \ln Y)^{-1} = \left[ \alpha_Y + \gamma_{YY} \ln Y + \sum_{i=1}^n \gamma_{Yi} \ln P_i + \sum_{k=1}^m \beta_{kY} \ln I_k \right]^{-1} \quad (4)$$

so there are scale economies (diseconomies) if SCALE is greater (less) than unity. The requirement that SCALE declines monotonically, as Y increases, holds if and only if  $\gamma_{YY} > 0$ . Given estimates of the parameters, and fixing the values of input prices and the industry - specific variables, setting (4) to unity and solving for Y allows the calculation of the output level at which such a firm's average cost is minimized. Dividing this output level into the total value of industry output suggests the

number of such firms that are consistent with average cost minimization.

### III. Data

Our sample comprises of 60 cross-section data points for the 1986/87 financial year; the latest available. Output is defined as total retail sales of electricity (kWh). The sample is characterised by a conglomeration of ESAs with small output - 52 of the 60 firms had an annual output of 500 GWh or less. Of the remainder, one (Auckland) had an output nearly seven times as great as this, more than ten times the average output, and only slightly less than the combined outputs of the next three largest EAS.<sup>4</sup>

Total cost is the sum of four input costs; those associated with labour, capital, electricity purchased and other. The last of these is measured as total reported expenditure in the year in question, less expenditures on labour, capital and on purchasing and (if applicable) generating electricity, less expenditures relating to the retailing of appliances. Accordingly, these costs essentially relate to maintenance and operation, administration, loan interest and depreciation. In the case of labour, total salaries and wages were adjusted to exclude amounts associated with any electricity generation or appliance sales, or capitalised in particular capital projects. Figures for the historic value of each ESA's assets were inflated and depreciated to allow for a life of 30 years. Different capital items were treated separately with respect to depreciation rates and method of depreciation

(diminishing value or straight line). This breakdown distinguished between distribution equipment; distribution and transmission buildings; public lighting; land; offices, stores and workshops; loose tools, plant and furniture; motor vehicles; and other capital items. Aggregate capital figures were then constructed. The cost of purchasing electricity includes that associated with purchases from ECNZ, plus any from firms involved in co-generation or from other ESAs. Generation costs (in the few cases, where relevant) were excluded from the analysis to ensure comparability across ESAs. A commensurate value was calculated and included in total electricity costs in such cases. Such values were calculated taking account of the structure of the Bulk Supply tariff, which distinguishes between winter zone and anytime demands; between day and night energy rates; and between location in the North and South Islands.

Input prices were defined as follows. The prices of labour and "other" inputs are the associated expenditures divided by the number of employees. Three possible definitions of the price of capital inputs were considered : total capital value divided by circuit kilometres of distribution line; the value of capital divided by the combined amount of circuit kilometres of distribution line plus kVA transformer capacity, expressed as circuit kilometre "equivalents"; a constant capital price across ESAs.<sup>5</sup> Two alternative measures of the price of electricity purchased were considered : total electricity cost divided by total electricity purchased and generated (cents/kWh); and constant values of 2.8084 cents/kWh for South Island ESAs, and 3.4318 cents/kWh for North Island ESAs.

Finally, we consider up to five industry-specific variables. These comprise dummy variables for the "type" of ESA ( $\ln(I_1) = 1$ , EPB;  $= 0$ , MED); and for ESA location ( $\ln(I_2) = 1$ , North Island;  $= 0$ , South Island); plus the load factor ( $I_3$ ); and density. Two possible measures of the latter were considered -  $I_4$  = number of consumers per square kilometre of licensed area; or  $I_4$  = number of consumers per circuit kilometre of distribution line. Also considered was a regional dummy variable ( $\ln(I_5) = 1$ , urban;  $= 0$ , rural). Further details of the data and their construction are given by Wyatt et al. (1989).

#### IV. Results

Joint ML estimation and the other computations were undertaken with the TSP package (Hall et al., (1988)). Equation (2) was constrained to avoid the multicollinearity that would otherwise arise because  $\ln(I_i) = (\ln(I_i))^2$  ( $i=1,2,5$ ). Not all of  $\beta_1$ ,  $\beta_2$ ,  $\beta_5$ ,  $\beta_{11}$ ,  $\beta_{22}$ , and  $\beta_{55}$  are identifiable in our model and so the relevant terms were coded as  $1.5 \beta_i \ln(I_i)$  ( $i=1,2,5$ ). When all of the industry-specific variables (however defined) were included in the model, the results were economically implausible: the estimates of  $\gamma_{yy}$  were negative. A sequence of nested model tests revealed the load-factor to be the main source of this problem<sup>6</sup>, although when it was removed from the model we were still unable to obtain plausible results with a significant rural - urban effect. Accordingly, we discarded these two regressors. A formal model - selection procedure was then used to determine the final specification of the model. Akaike's Information Criterion (AIC)

was used to discriminate between the non-nested specifications that arise with the alternative definitions of density and the prices of capital and electricity purchased. With the variable definitions fixed, a sequence of nested Likelihood Ratio tests (LRTs) was used to determine whether the model should be simplified further by deleting other industry-specific variables. These asymptotic tests were applied in the manner described by Mizon (1977) so as to control their true size.

This procedure favoured the first of the measures of density and electricity price, and the second measure of capital price. With these definitions, the results of our LRTs appear in Table 1. Two non-nested specifications cannot be rejected, so the final selection is again based on AIC, resulting in the retention of density and the "type" of ESA as the industry-specific variables. The lack of significance of the North - South dummy apparently reflects the fact that the electricity purchase price variable is already capturing the relevant effects. The ML estimates of the model's parameters appear in Table 2.

Each variable enters the model in several forms. The overall significance of the industry-specific variables has been established via the LRTs. Individually, many of the parameters are also significant. Signing the parameters is not trivial. The relevant issue is the sign of the partial derivative of  $C$  with respect to the variable of interest. Equivalently we can sign the associated elasticity, which is more easily derived, given the form of (2). For example, we expect  $\partial \ln C / \partial \ln Y$  (=SCALE) and  $\partial \ln C / \partial \ln P_i$  ( $= S_i$ ) ( $i=1, \dots, 4$ ) to be positive; and in the case of "density",  $\partial \ln C / \partial \ln I_4 < 0$ . The anticipated sign for the ESA

"type" dummy variable is ambiguous. Using the estimated parameters from Table 2 we have evaluated each of these derivatives at each point in the sample. There are no exceptions to the anticipated signs, and the estimated shares are all positive fractions. Given the imposition of the restriction  $\sum_i \gamma_{yi} = 0$ , homotheticity of the underlying production function would imply  $\gamma_{y1} = \gamma_{y2} = \gamma_{y3} = 0$ . Adding the additional restrictions  $\gamma_{yy} = \beta_{1y} = \beta_{4y} = 0$  implies homogeneity of the production function. Homotheticity and homogeneity are both rejected by LRTs (see Table 1), and so are not imposed in the following analysis. Ordering the data by increasing value of output, there is no evidence of heteroskedasticity in the residuals.

Estimated scale economy measures appear in Table 3. These are obtained from (4) in two ways - first, as is conventional,  $\overline{\text{SCALE}}$  is calculated with all variables except output fixed (here, to their sample means); and secondly,  $\text{SCALE}$  is calculated at each individual sample point.<sup>7</sup> The latter figures are interesting, but the former are of primary importance and only on these can cross-firm comparisons be based. The point estimates of  $\overline{\text{SCALE}}$  suggest there are economies of scale in this industry - numerically, all of these values exceed unity, except for that of Auckland, the ESA with by far the largest output. The Wald test is used to test the hypothesis of unitary economies of scale. As the reciprocal of a Normal random variable has infinite variance, we actually test the (equivalent) hypothesis that the reciprocals of  $\overline{\text{SCALE}}$  and  $\text{SCALE}$  are unity.<sup>8</sup> The results appear in Table 3, where we see that for 25 of the 60 output levels in our sample, the  $\text{SCALE}$  estimates which are significantly greater than unity. No such estimate is

significantly less than unity - even at the level of output experienced by the Auckland ESA there is no significant evidence that scale economies have been exhausted. This reinforces the earlier comment that there is evidence of scale economies in New Zealand electricity distribution.

The Average Cost (AC) curve implied by our estimated Translog model appears in Figure 1, evaluated with all variables other than output set to their sample means. It exhibits the typical "flat" region mentioned in Section I: AC is minimised ( $\overline{SCALE} = 1$ ) at an annual output of 2,315 GWh, but casual observation suggests that any output in the range 500 - 3,500 GWh is essentially consistent with minimum AC. In 1986/87, total output for the industry was 19,444 GWh, so we see that eight or nine "typical" ESAs with equal output would have ensured AC minimisation. Taking account of the flat section of the AC curve suggests that up to 39 such ESAs would not have been inconsistent with this objective. This number can be formalised by noting that the asymptotic standard error associated with the AC-minimizing number of "typical" firms (8.4) is 19.855, so a 90% confidence interval puts an upper bound of 41 on this number of ESAs.

As a sensitivity test of our results we re-specified the model to include only three input costs: the cost of electricity was discarded, total cost was re-defined accordingly, and the complete analysis was replicated. The preferred model specification used the second definitions of density and capital price, and the North-South dummy variable was retained. Our broad conclusions were unaltered: average cost was minimised at 1,748 GWh p.a., implying eleven firms in the industry; a 90% confidence interval

on this number of firms allows for up to 40 ESAs without departing significantly from AC-minimisation; more than half of the SCALE and SCALE estimates were significantly greater than unity, and only one was numerically (but not significantly) less. Full details are given by Wyatt et al.<sup>9</sup>

## V. Conclusions

This paper uses a Translog cost model to estimate economies of scale in electricity distribution in New Zealand. We find evidence that the number of firms currently in the industry is greater than that consistent with Average Cost minimisation. Our results indicate that at the output levels associated with more than a third of the firms in our sample, there are significant scale economies, and that these economies are not (significantly) exhausted even at the highest sample output value. Not surprisingly, the number of Electricity Supply Authorities in this country has attracted attention over the years. Our results show this attention to be justified - with Figure 1 in mind, and calculating the total industry cost with eight identical firms operating at AC-minimising output, we find there would be a 15.5% reduction in this total cost relative to that which prevailed in our 1986/87 sample. Even reducing the number of firms from 60 to 40 implies an 8% reduction in total industry cost on this basis.<sup>10</sup>

Such figures must be treated cautiously. Our model has been specified carefully but it cannot capture the full detail of this industry. The firms in it are not homogeneous. Each has its individual features, which of course preclude the attainment of

the hypothetical situations just described. We offer no prescription for the amalgamation of Supply Authorities. Clearly, there are important geographic, technical and social constraints that would have to be taken into account. This industry is undergoing changes, and further deregulation has been mooted. Subject to the constraints noted, our results suggest the likely future shape of the industry if Supply Authorities were to rationalise their activities in a more competitive environment.

TABLE 1. -TESTS OF NESTED HYPOTHESES

(a) Model Specification Tests				
Industry-Specific Variables Included				
Maintained Hypothesis	Restricted Hypothesis	LRT <sup>a</sup>	$\nu$	AIC
$(I_1, I_2, I_4)$	$(I_1, I_2)$	N.A. <sup>b</sup>	-	-
$(I_1, I_2, I_4)$	$(I_2, I_4)$	11.97	7	-16.97
$(I_2, I_4)$	$I_2$	N.A. <sup>b</sup>	-	-
$(I_2, I_4)$	$I_4$	20.26 <sup>c</sup>	6	-
$(I_1, I_2, I_4)$	$(I_1, I_4)$	8.76	7	-17.03
$(I_1, I_4)$	$I_4$	23.46 <sup>c</sup>	6	-
$(I_1, I_4)$	$I_1$	N.A. <sup>b</sup>	-	-
(b) Homotheticity Test <sup>d</sup>				
Maintained Hypothesis	Restrictions	LRT	$\nu$	
See Table 2.	$\gamma_{y1} = \gamma_{y2} = \gamma_{y3} = 0$	20.40 <sup>c</sup>	3	

a. LRT is asymptotically  $\chi^2$  with  $\nu$  degrees of freedom.

b. Estimated coefficients conflict with prior economic theory.

c. Significant at the 1% level or higher.

d. Homogeneity restrictions are nested within homotheticity restrictions, so the former are rejected. Testing separately for homogeneity also leads to rejection:  
LRT = 21.86 ( $\nu = 6$ ).

TABLE 2. - MAXIMUM LIKELIHOOD ESTIMATES

Parameter	Estimate (Asymptotic "t-value")	Parameter	Estimate (Asymptotic "t-value")	
$\alpha_0$	7.775 (1.98)	$\alpha_1$	-0.060 (-0.57)	
$\alpha_y$	0.661 (1.49)	$\alpha_2$	-1.170 (-6.30)	
$\gamma_{yy}$	0.031 (1.18)	$\alpha_3$	2.155 (9.10)	
$\gamma_{y1}$	-0.004 (-2.56)	$\beta_1$	-0.148 (-0.16)	
$\gamma_{y2}$	-0.018 (-2.06)	$\beta_4$	0.267 (1.04)	
$\gamma_{y3}$	0.023 (2.93)	$\beta_{44}$	0.001 (0.39)	
$\gamma_{22}$	0.197 (14.73)	$\beta_{14}$	-0.068 (-1.34)	
$\gamma_{32}$	-0.168 (-15.03)	$\beta_{1y}$	-0.037 (-0.50)	
$\gamma_{42}$	-0.013 (-3.75)	$\beta_{4y}$	-0.002 (-0.14)	
$\gamma_{33}$	0.183 (10.84)	$\theta_{11}$	-0.010 (-1.56)	
$\gamma_{43}$	-0.000 (-0.74)	$\theta_{12}$	0.150 (4.16)	
$\gamma_{41}$	-0.018 (-4.99)	$\theta_{13}$	-0.126 (-3.87)	
		$\theta_{41}$	0.002 (1.87)	
		$\theta_{42}$	-0.028 (-4.05)	
		$\theta_{43}$	0.024 (3.92)	
Equation:	$\ln C$	$S_1$	$S_2$	$S_3$
$R^2$	0.964	0.661	0.485	0.433

Note: Estimates of remaining parameters are derivable from the homogeneity and symmetry restrictions. Asymptotic "t-values" (in parentheses) are Standard Normally distributed.

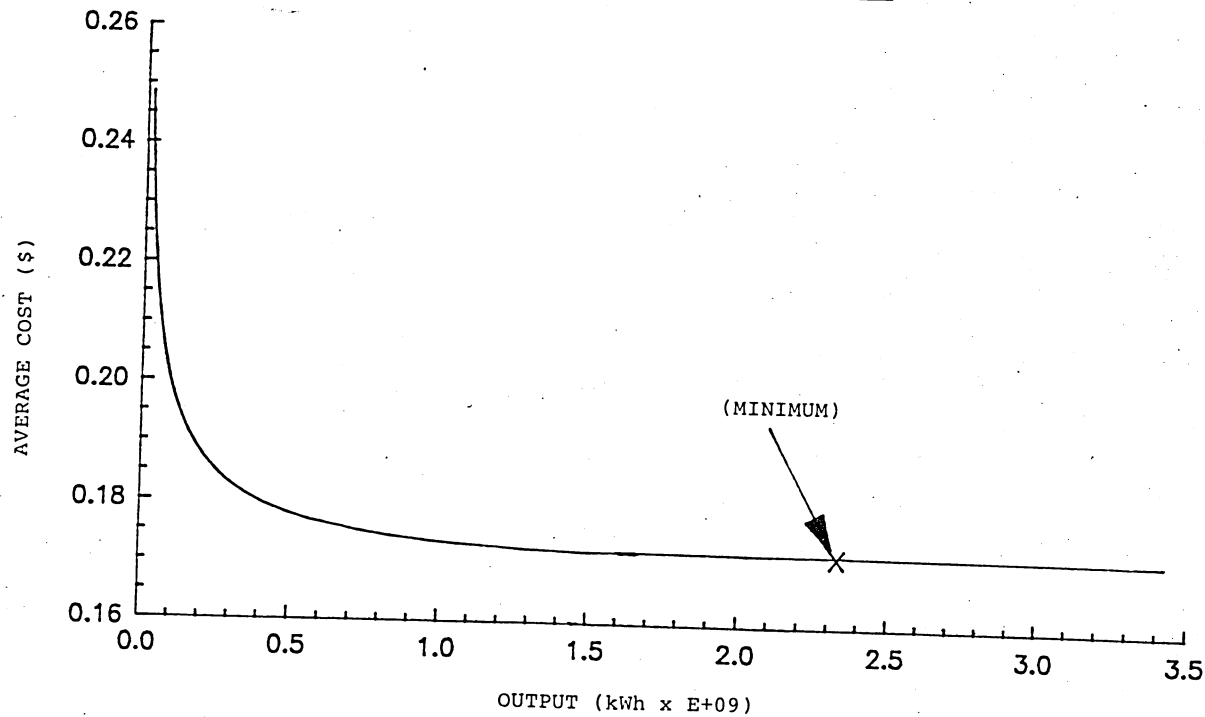
TABLE 3. - SCALE ECONOMY MEASURES

SUPPLY AUTHORITY	OUTPUT (E+09 kwh)	SCALE	SCALE
1 ASHBURTON	0.158	1.090 (3.85)**	1.093 (1.35)
2 AUCKLAND	3.426	0.988 (0.01)	1.016 (0.02)
3 BAY OF ISLANDS	0.194	1.082 (3.11)*	1.080 (1.12)
4 BAY OF PLENTY	0.402	1.057 (0.70)	1.067 (0.43)
5 BLUFF	0.017	1.177 (1.41)	1.146 (1.16)
6 BULLER	0.082	1.114 (3.43)*	1.117 (1.46)
7 CAMBRIDGE	0.087	1.112 (3.56)*	1.119 (1.42)
8 CENTRAL CANTERBURY	0.427	1.055 (0.61)	1.066 (0.50)
9 CENTRAL HAWKES BAY	0.082	1.114 (3.44)*	1.101 (1.59)
10 CENTRAL WAIKATO	0.486	1.050 (0.44)	1.061 (1.05)
11 CHRISTCHURCH	1.475	1.014 (0.01)	1.012 (0.01)
12 DANNEVIRKE	0.070	1.120 (3.08)*	1.124 (2.11)
13 DUNEDIN	0.731	1.037 (0.15)	1.018 (0.02)
14 EGDMONT	0.191	1.082 (3.17)*	1.086 (2.03)
15 FRANKLIN	0.248	1.073 (2.06)	1.075 (1.81)
16 HAMILTON	0.136	1.095 (4.10)**	1.082 (2.77)*
17 HAWKES BAY	0.565	1.045 (0.30)	1.058 (0.65)
18 HOROWHENUA	0.257	1.072 (1.91)	1.094 (2.28)
19 HUTT VALLEY	0.967	1.027 (0.07)	1.058 (0.71)
20 INVERCARGILL	0.216	1.078 (2.65)	1.073 (5.03)**
21 KAIAPOI	0.022	1.166 (1.57)	1.162 (1.45)
22 KING COUNTRY	0.086	1.112 (3.54)*	1.092 (1.20)
23 MANAWATU-OROUA	0.306	1.066 (1.32)	1.076 (1.43)
24 MARLBOROUGH	0.178	1.085 (3.46)*	1.091 (1.04)
25 NAPIER	0.076	1.117 (3.26)*	1.122 (2.64)
26 NELSON	0.109	1.103 (4.00)**	1.105 (6.30)**
27 NEW PLYMOUTH	0.272	1.070 (1.71)	1.050 (0.22)
28 NORTH AUCKLAND	0.417	1.055 (0.64)	1.062 (0.64)
29 NORTH CANTERBURY	0.198	1.081 (3.03)*	1.082 (0.78)
30 OTAGO	0.157	1.090 (3.86)**	1.079 (0.78)
31 OTAGO CENTRAL	0.204	1.080 (2.90)*	1.083 (0.61)
32 PALMERSTON NORTH	0.180	1.085 (3.42)*	1.072 (2.91)*
33 PORT HILLS	0.079	1.115 (3.16)*	1.106 (3.48)*
34 POVERTY BAY	0.207	1.080 (2.84)*	1.081 (1.15)
35 RICCARTON	0.049	1.134 (2.42)	1.147 (1.57)
36 ROTORUA	0.285	1.068 (1.55)	1.080 (1.65)
37 SOUTH CANTERBURY	0.260	1.072 (1.87)	1.079 (0.68)
38 SOUTHLAND	0.424	1.055 (0.62)	1.046 (0.14)
39 TARANAKI	0.250	1.073 (2.03)	1.078 (0.98)
40 TARARUA	0.046	1.136 (2.33)	1.134 (1.69)
41 TASMAN	0.297	1.067 (1.42)	1.080 (0.76)
42 TAUMARUNUI	0.021	1.169 (1.53)	1.140 (1.94)
43 TAUPU	0.162	1.089 (3.78)*	1.058 (0.10)
44 TAURANGA MED	0.056	1.128 (2.65)	1.120 (1.55)
45 TAURANGA EPB	0.349	1.061 (0.98)	1.075 (1.69)
46 TE AWAMUTU	0.102	1.106 (3.89)**	1.111 (2.02)
47 THAMES VALLEY	1.062	1.024 (0.05)	1.029 (0.08)
48 THAMES-COROMANDEL	0.030	1.154 (1.82)	1.115 (1.51)
49 TIMARU	0.120	1.100 (4.09)**	1.108 (3.43)*
50 WAIRARAPA	0.195	1.082 (3.08)*	1.089 (1.43)
51 WAIROA MED	0.019	1.171 (1.49)	1.159 (1.42)
52 WAIROA EPB	0.038	1.144 (2.07)	1.130 (1.55)
53 WAITAKI	0.146	1.092 (4.01)**	1.100 (1.35)
54 WAITEMATA	1.280	1.019 (0.02)	1.030 (0.16)
55 WAITOMO	0.113	1.102 (4.04)**	1.097 (1.39)
56 WANGANUI-RANGATIKEI	0.351	1.061 (0.97)	1.060 (0.55)
57 WELLINGTON	0.837	1.032 (0.10)	1.020 (0.04)
58 WEST COAST	0.118	1.100 (4.09)**	1.113 (1.08)
59 WHAKATANE	0.038	1.143 (2.08)	1.130 (1.63)
60 WHANGAREI	0.092	1.109 (3.69)*	1.104 (2.80)*
AVERAGE	0.324	1.088	1.087

Note:  $\chi^2_{(1)}$  Wald-test values appear in parentheses.

\* Significantly different from unity at 10% level.  
 \*\* Significantly different from unity at 5% level.

FIGURE 1 - ESTIMATED TRANSLOG AC CURVE



34	18	4	3	0	0	0	1
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ESAs (FREQUENCY DISTRIBUTION)

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#### FOOTNOTES

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1. Six major industrial users purchase bulk electricity direct from the national grid. They are excluded from this study.
2. Recently, this number has been reduced to 58, and negotiations for further amalgamations are in progress.
3. Recent changes to the industry include the potential for ESAs to bargain directly with ECNZ over the price of bulk electricity and changes to taxation arrangements for ESAs. In addition, some Government Ministers have expressed the view that ESAs should be commercialised and run as companies under the Companies Act. In future, ESAs may become more profit oriented.

4. All of our analysis was repeated with the Auckland observation excluded from the sample. The numerical estimates changed only slightly from those reported below, and none of the conclusions were altered.
5. In this case the implications of the estimation results are, of course, independent of the figure chosen.
6. There is evidence of multicollinearity, in terms of both the simple and multiple correlations between this variable and the other regressors.
7. As the estimate of  $\gamma_{yy}$  in Table 2 is positive, the  $\overline{\text{SCALE}}$  estimates decrease monotonically with increasing output. This is not the case for SCALE, of course.
8. Conditional on a set of data values, (4) is the reciprocal of a linear combination of certain parameters. The ML estimates of the latter are asymptotically Normally distributed, as is any linear combination of them. Accordingly, it makes little sense to report "asymptotic standard errors" for estimates of  $\overline{\text{SCALE}}$  or SCALE.
9. That paper also reports some tentative, and only partially successful, attempts to model the ESAs as dual-output firms, supplying both "energy" (in kWh) and "power" (in kWh). This was motivated by the peak-load problem and the ESAs' limited ability to smooth their loads. The aggregate scale economy estimates obtained were totally consistent with those reported here.
10. In the case of our three-input model these industry cost savings are 21% and 17.5% respectively.

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