An Inter-Sector Analysis of Electric Utilities in Newfoundland

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This paper investigates differences in productivity and cost structure between private and public utilities in Newfoundland, 1956-91. A conventional accounting approach, and a four-input translog cost function and associated share equations are used to estimate total and partial factor productivities, own and cross-partial elasticities of input demand and substitution, technical change, and scale economies. Differences in productivity are traced to the patterns of factor-bias of technical change, factor complementarities, and returns to scale. We find capital-using bias and diseconomies of scale in private utilities, and capital-saving bias and economies of scale in public utilities. The implications of these findings for policy warrant further study. Although preliminary, our results do not support the hypothesis that private utilities are more efficient than those in the public sector.

Cette étude étudie les différences de productivité et de structure de coûts entre les fournisseurs d'énergie publics et privés à Terre-Neuve entre 1956 et 1991. On utilise une approche de comptabilité conventionnelle et une fonction logarithmiques des coûts à quatre facteurs ainsi que des équations relatives aux parties associées pour obtenir une estimation de la productivité totale et partielle des facteurs, de l'élasticité propre et inter-parties de demande et de substitution, des changements techniques et des économies d'échelle. Les causes des différences de productivité d sont attribuées aux modèles de biais factoriels relatifs aux changements techniques, à la complementarité des facteurs et aux retours à l'échelle. On retrouve des biais utilisant le capital et des déséconomies d'échelle chez les fournisseurs d'énergie privés et des biais d'économie de capital et d'économies d'échelle chez les fournisseurs publics. Les implications de ces études en terme d'élaboration des politiques demandent des études complémentaires. Il convient de noter que nos résultats préliminaires ne permettent pas de corroborer l'hypothèse selon laquelle les entreprises du privé soient plus efficaces que celles du secteur public.

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Introduction

In few industries do issues of appropriate ownership and regulatory structure attract more attention by regulators, policy-makers and the general public than in electric utilities. Not only do electricity and the industry that supplies it play an important role in most economies, but the sheer size of the capital requirement, its longevity, natural resource intensity and potential scale economies tend to keep ownership issues in the focus of public policy. A few years ago the provincial government proposed to restructure and privatize Newfoundland and Labrador Hydro, Canada's fourth largest utility and the Province's largest crown corporation.[1] Although the specific objective was "to achieve the most efficient and effective provincial electrical industry" (Wells, 1993), the effort was abandoned in the face of widespread public protest. The apparent reversal on the merits of private ownership was taken one step further recently when the government entered formal negotiations with Hydro-Quebec to develop, without private sector participation an additional 3,200 MW of power from the Churchill River system.[2] This

1/ With about 1,000 employees and $1.6 billion in assets. privatization was expected to raise more than $1 billion to slash the provincial debt.

2/ The project is to be owned 65.8% by Newfoundland and Labrador Hydro and 34.2% by Hydro-Quebec. The move runs counter to the deregulation and innovation currently transforming the industry in Canada and world-wide. A charitable interpretation of this strategy is that the government has embraced the "no difference in efficiency" argument with regard to ownership. According to Vining and Boardman (1992) there are two ways of reaching the conclusion that ownership does not matter for allocative efficiency. The first is to argue as does Whitehead (1989:9) that "there is no inherent reason why enterprises in private ownership should operate more efficiently than those in public ownership." This argument assumes no difference in the production of socio-political output (produced in addition to their "core" output.) But as the authors point out, this is contradicted by the proponents' view of public utilities as a policy tool. The second argument is that public utilities are technically and allocatively efficient but produce socio-political output that is not taken into account in standard efficiency studies. The problem with this argument is that the extent to which public utilities raise employment, wages, and produce other socio-political output necessarily comes at the expense of profitability. In an economy-wide review of more than 90 comparative ownership studies, Vining and Boardman (1992) conclude that ownership matters for both technical and allocative efficiency. The evidence for electric utilities (summarized in Table 1) favour private ownership on efficiency grounds. In the case of Newfoundland, this study does not. We offer two plausible explanations for this finding. The first turns on inter-sectoral differences in the subsidization of key inputs. The second explanation recognizes that the geographic monopoly of most electric utilities tend to preclude direct competition in the product market. Where substantial scale economies, high entry barriers or externalities are present, public ownership may be preferred.

Our analysis assumes that the primary long-term objective of public policy toward the electric utility industry is economic efficiency. We then seek to test the hypothesis that private (investor-owned) electric utilities are more efficient than their public sector counterparts. This paper does not address regulatory and marketing issues, investment financing aspects, or royalty regimes. The only dimension of economic efficiency that concerns us here is the cost of supplying electricity, as manifested in inter-sectoral differences in productivity and production structure.

In the past two decades numerous empirical studies have been published characterizing the behaviour and technology of such utilities in various countries. Most previous studies have focused on the effects of regulatory change on productivity and technical progress, and concern fossil-fuelled steam-electric generation either by investor-owned utilities or public utilities in the United States. The results through 1978 are surveyed by Cowing and Smith (1978). More recent work based on flexible functional forms and frontier cost function specifications include Stevenson (1980), Jorgensen and Fraumeni (1981), Joskow and Noll (1981), Gollop and Roberts (1981), and (1983), Christensen *et al.* (1983), Nelson and Wohar (1983), Joskow (1987), Nelson (1986) and (1990b). One of the very few Canadian studies of electric utilities is Daly and Rao (1983) who use time-series data for Ontario Hydro to explore sources of productivity growth using a translog approach. The present study extends consideration of these issues to an inter-sectoral comparison using both a translog and a growth accounting framework. Ideally, one would like to estimate the production structure of privately and publicly owned utilities separately. Unfortunately, the data available for public utilities do not provide the requisite degrees of freedom. The short time-series available since the emergence of public utilities in the Province, and insufficient cross-sectional and panel data necessitates the approach taken here. Our comparative analysis is based on models estimated on time-series data for private utilities and an aggregate of private and public utilities called "all utilities." With separate data available for private utilities, important characteristics of public utilities can be inferred.

The paper is organized as follows. Section II outlines the historical context that shaped the industry. A conventional accounting approach is then used to discuss the sector-specific trends in factor productivity. In section III, the model of the electric utility is represented by a translog cost function. Section IV discusses the data, estimation

public investment of $9.7 billion, forecast over ten years, includes the partial diversion of two rivers in Quebec and power transmission infrastructure to be developed and owned by Hydro-Quebec and local communities.

Table 1: Empirical Results on Relative Efficiency of Public and Private Electric Utilities

Public utility more efficient	No difference/ambiguous	Private utility more efficient
Meyer (1975)	Mann (1970)	Shepherd (1966)
Neuberg (1977)	Yunker (1975)	Moore (1970)
Pescatrice & Trapani (1980)	Dilorenzo & Robinson (1982)	Peltzman (1971)
Färe *et al.* (1985)	Tilton (1973)	De Alessi (1974a)[1], (1977)
Atkinson & Halvorsen (1986)		Pollitt (1994)

1/ See also De Alessi (1974b), and Nelson (1990a).

procedure and results. Section V, finally, highlights inter-sectoral differences by drawing together results from the accounting and econometric approaches. This section also presents our conclusions.

Growth of Electric Utilities: An Accounting Approach[3]

The electric power industry can be divided into privately-owned and publicly-owned sectors although the industry is more diverse and complex than these categories imply. The structure of electric utilities is usually described as having three distinct segments: generation, transmission, and distribution. Although accounting data are collected accordingly, Joskow and Schmalensee (1983) point out that the three segments are not necessarily distinct in any economically meaningful way, nor can they necessarily be operated independently of one another. We adopt this view and do not distinguish between the three segments of the industry. In any case, the industry is highly capital-intensive, and capital structures are site-specific, specialized to the electric power industry and very long-lived.

Between 1956 and 1991 the output of electric utilities grew at an average rate of 97% per annum while real provincial GDP grew at 8.4%. Total factor productivity growth in electric utilities also appears to have increased at a considerably faster pace than that of the provincial economy as a whole.[4] A brief review of the historical context casts some light on these observations. The trend in installed generating capacity (Figure 1) reveals four distinct phases in the development of electrical power in Newfoundland. The first phase (1855-1953) saw the installation by private electric utilities of the first generating and distribution facilities. In phase two (1954-1966) the public utility sector emerged in response to the private sector's inability to provide rural electrification and adequate power supply for industrial expansion.[5] The mandate of the Newfoundland Power Commission and the Rural Electrification Authority was to develop a major hydro-electric project at Bay d'Espoir, and construct an Island-wide high-voltage transmission grid. This lead gradually to a termination of further power development by the private sector, and the eventual merger, in 1966, of the three private utilities. The third phase (1967-1980) began with industrialization facilitated by new public sector generating and transmission capacity. Domestic demand for electricity also grew very rapidly in response to rising personal income and the active promotion of electric home heating. The anticipated growth in demand resulted in the construction of additional power facilities, notably the massive Churchill Falls hydroelectric power project in central Labrador. Upon completion in 1974 the government bought a controlling interest in the project from the private sector developers.[6] The fourth phase (1981-91)

3/ The attractiveness of this approach is that it does not depend on any assumption about optimizing behaviour on the part of the producers (assumptions that may not be satisfied). This approach is consistent with the use of accounting data whereas approaches that rely on cost minimization (see section IV) should use ex-ante data on prices, and these data are not observable in general (Diewert, 1991). However, it should also be noted that the productivity measures derived from the accounting approach assume a CRS structure, static equilibrium for the firm and Hicks-neutral technical change (see e.g. Caves *et al.*, 1981).

4/ See Table 2 and Anon. (1991).

5/ By the late 1940s the mills used 93% of the power produced. Only about 50% of the population had electricity (Kennedy 1967). See also Baker *et al.* (1990) for a history of private electric utilities in Newfoundland.

6/ In 1975 the Power Commission was replaced by Newfoundland and Labrador Hydro which now centralizes under one authority the control and management of all public interests in electrical generation, transmission and distribution. The public sector now consists of five electric utilities: Newfoundland and Labrador Hydro, Churchill Falls (Labrador) Corporation, Lower

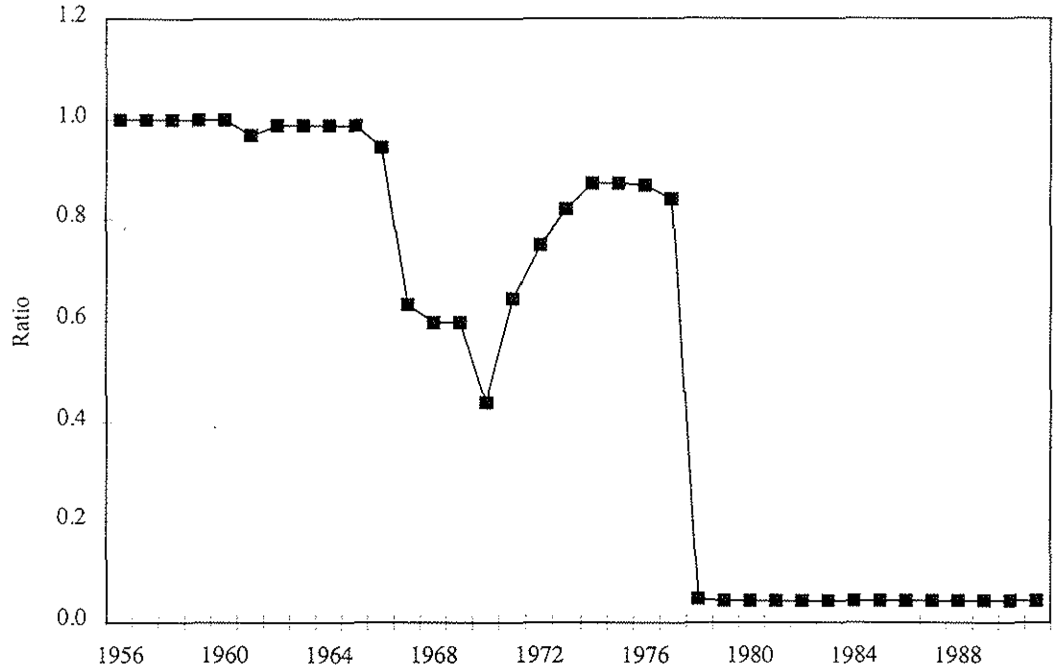

Figure 1: Private generating capacity to total

commenced with the full development of the principal hydroelectric power potential on the Island portion of the province. The period is characterized by negative average growth rates in output and capacity usage for all sectors.

The trends in output, capacity usage, and real input costs during these historical periods are telling (Table 2). The relative peaks in output and capacity growth coincide with the establishment of the first major public utility in the late 1960s. In all other subperiods the growth rates in capacity usage[7] are negative in both sectors (and more so in the public sector[8] proper). The most noteworthy feature of the data is that with one exception, the factor cost growth rates are higher for public utilities than for private utilities. This raises the question of how productively electrical utilities use inputs, in combination and in total. That is, what are the determinants of multifactor productivity and single-factor average productivity, and how does productivity vary across sectors? To examine this issue, we assume that the technology can be represented by a production function f:

$$Q = f(X_1, \ldots, X_n, T) \qquad (1)$$

where Q denotes output, and the X_i are inputs. The variable T is an index of the level of technology, representing the way in which feasible input combinations are affected by technological progress, i.e., multifactor productivity. We use two productivity measures for purposes of comparison. The first, Partial Factor Productivity (PFP) is the ratio of Q to the quantity employed of each of four input aggregates:[9] labour (L), capital services (K), fuel (F), and non-fuel intermediate materials (M). Although PFP (or average factor productiv-

Churchill Development Corporation, Twin Falls Power Corporation, and Gull Island Power Corporation. See also fn. 39.

7/ Note that while installed capacity is a useful measure of electric utility size in many instances, capacity usage must be interpreted with care. The problem with this measure is that it does not reflect the acquisition of assets other than capital structures. Capacity usage does not necessarily reflect the current size of the utility because over-investment in early periods may inflate the measure of installed capacity implying that the asset base is larger than the real asset base currently in use.

8/ Since "all utilities" is some average of private and public utilities, and the values for private utilities are known it is possible to infer the relative magnitude of the growth rate in the public sector.

9/ The growth rate of PFP may thus be defined as

$$\dot{PFP_i} = (\frac{\dot{Q}}{X_i})$$

Table 2: Average Annual Growth Rates in Output, Capacity Usage, and Real Factor Cost (%), 1956-91

	$\dot{Q}$	$\dot{CU}$	$W_L\dot{X}_L$	$W_K\dot{X}_K$	$W_F\dot{X}_F$	$W_M\dot{X}_M$
			All Utilities			
1956-66	12.2	-1.2	11.2	12.8	59.3	89.2
1967-80	116.0	5.0	18.2	23.5	41.1	17.2
1981-91	-1.6	-2.1	1.4	3.2	0.8	-0.5
1956-91	97.0	-0.4	28.9	35.1	485.7	115.6
			Private Utilities			
1956-66	12.0	-0.9	11.2	12.8	59.3	34.3
1967-80	-1.6	0.9	2.3	-1.29	34.8	3.9
1981-91	-0.3	-0.4	0.3	2.6	3.6	2.4
1956-91	2.0	-0.08	7.5	5.4	338.2	21.2

Note: Price growth rates are in real terms, and
Q - total generation in kilowatt-hours
$W_L X_L$ - average cost of labour
$W_K X_K$ - average cost of capital
$W_F X_F$ - average cost of fuel
$W_M X_M$ - average cost of material
CU - capacity usage
Source: Statistics Canada and Newfoundland Statistics Agency

ity) captures the rate at which a productive input is transformed into output it must be interpreted with caution: PFP is an inadequate measure of efficiency since it cannot distinguish between overall efficiency gains and gains arising from an increase in the use of other inputs. Total factor productivity (TFP) is a better measure of overall efficiency gains since it measures the increase in output that is not explained simply by the use of more inputs. That is, TFP measures the electric utility sector's ability to obtain increasing amounts of real output from given levels of all inputs. TFP may be defined as the ratio of Q to an index of aggregate inputs.[10]

Curious sectoral differences in productivity growth are observed (Table 3.)·With regard to the partial factor productivities it is noteworthy that the public sector proper exhibits relatively higher PFP growth rates in all but one sample period. In the private sector, all PFP and TFP growth rates are, on average, negative after the public sector becomes a major electricity provider in the late 1960s. But the trend in TFP growth signals increasingly wise use of all scarce inputs over time. A different pattern emerges for the public sector. When the private sector is netted out of "all utilities," we observe an initial period of strong TFP growth, followed by declining and eventually negative rates of growth.[11] What accounts for these variations? A priori, falling TFP growth may be explained by falling rates of output and technical change; or by a decrease in scale economies as the physical limits to further hydroelectric capacity expansion is reached. To determine which factors are responsible for the fall in productivity requires knowledge of the extent of scale economies. But before we turn to an econometric analysis of these issues, certain underlying conditions should be recognized.

During 1967-80, technical change and the construction of new generating capacity resulted in phenomenal increases in both output and TFP growth. We hypothesize that part of the TFP growth was due to scale economies in the public sector. However, the optimal size of new facilities depends on system growth as well as scale economies. Since actual capacity usage requirements were growing only slowly the construction of large public sector units produced a large amount of excess capacity on average as manifested in the data presented.[12] Hence, the negative rate of TFP growth for the period in question.

The construction and subsequent transfer of the new capacity from the private sector to the public sector in the 1967-80 effectively marginalized private hydroelectric utilities once and for all. The resulting sharp fall in production by private utilities is associated with negative growth rates in capacity usage (Table 2).[13] The transfer of capital structures and the absence of subsequent construction of generating capacity are reflected also in the

10/ If A is the index of aggregate inputs, and if it is computed using a Divisia index, its proportionate growth rate $\dot{A}$ can thus be defined as

$$\dot{A} = \sum_i S_i \dot{X}_i$$

where $S_i = W_i X_i / TC$, is the cost share of the *i*th input; W_i is the price of the *i*th input; TC is total cost and $\dot{X}_i$ is the growth rate of X_i. The growth rate of TFP can then be expressed as

$$\dot{TFP} = \dot{Q} - \dot{A}$$

11/ This is largely consistent with studies for the United States reviewed by Joskow (1987).

12/ Cf. Gibbons (1992).

13/ We have not adjusted our capital stock data for capacity usage as this would overestimate TFP growth.

Table 3: Average Annual Growth Rates in Partial Factor Productivity and Total Factor Productivity, 1956-91 (%)

	Growth in Partial Productivity of				
	Labour	Capital	Fuel	Material	TFP
All Utilities					
1956-66	4.4	1.3	-8.0	-6.8	-22.9
1967-80	49.6	27.8	32.2	75.7	103.0
1981-91	-1.2	-2.1	-1.9	3.0	-1.2
1956-91	28.3	10.6	-2.2	9.7	-17.5
Private Utilities					
1956-66	4.2	-1.3	-5.3	-3.9	-5.1
1967-80	-0.4	-1.4	-5.4	1.2	-4.3
1981-91	-0.3	-2.6	-1.2	2.8	-1.2
1956-91	1.0	-1.7	-2.6	0.2	-21.1

(negative) growth rate in private sector capital expenditure. We speculate that the reorganization of the ownership structure simply failed to leave the private sector with the least-cost mix of generating plants to meet actual increases in demand. The resulting long-run production inefficiencies and diseconomies of scale in the private sector thus prevented private electric utilities from deriving lasting benefits from the industry-wide TFP growth.

The Translog Cost Function

The preceding section used a growth accounting framework to highlight trends in productivity. This section employs an econometric model in an attempt to explain why input demands changed over time. The model views the power utility as a price-taker in all markets attempting to satisfy the expected gross output at the lowest cost.[14] The prices and levels of output are thus treated as exogenous variables in the estimation of the unknown parameters. If the power utility minimizes the cost with respect to all inputs and there is a convex input structure, there exists a total cost function, dual to (1), that relates the minimum production cost to output quantity, input prices, and the state of technology:[15]

$$C = C(Q, W_i, T) \qquad (2)$$

where all variables are as defined above. A continuously twice-differentiable, second-order approximation to such an arbitrary cost function is the translog cost function. It can be written

$$\begin{aligned}\ln C = {} & \alpha_0 + \alpha_Q \ln Q + \alpha_T \ln T + \sum_i \alpha_i \ln W_i \\ & + 1/2\,\alpha_{QQ} (\ln Q)^2 + 1/2 \sum_i \sum_j \alpha_{ij} \ln W_i \ln W_j \\ & + 1/2\,\alpha_{TT} (\ln T)^2 + \sum_i \alpha_{iQ} \ln W_i \ln Q \\ & + \alpha_{QT} \ln Q \ln T + \sum_i \alpha_{iT} \ln W_i \ln T \\ & i, j = L, K, F, M \end{aligned} \qquad (3)$$

It is well known that the flexible functional form avoids *a priori* parameter restrictions[16] that may bias coefficient estimates. For the cost function to be well behaved for all input price combinations, it must be both monotonic and concave[17]

14/ Cf. Christensen and Greene (1976) and others. Although the non-econometric evidence surveyed by De Alessi (1974a) suggests that private and public utilities behave differently, indications to the contrary come from extensive testing of the Averch-Johnson overcapitalization hypothesis. Joskow and Noll (1981) review the evidence for the electric industry and do not find unambiguous support for this hypothesis.

15/ Cost minimization does not require that the utilities know their demand curve. The procedure is also invariant to the degree of competition in the output market. We are concerned with both investment and operating decisions: assuming that an appropriate mix of base-load, cycling and peak-load capacity is installed, and that the equipment is operated to optimize system stability and reliability. This ensures that the facilities themselves will have been built at minimum cost.

16/ The standard theoretical requirements that the cost function be homogeneous of degree one in input prices, and that the second-order coefficients of the Hessian be symmetrical (i.e., $\alpha_{ij}=\alpha_{ji}$) reduce the number of coefficients to be estimated as they imply the following set of restrictions:

$$\sum_i \alpha_i = 1, \quad \sum_i \alpha_{ij} = \sum_i \alpha_{iQ} = \sum_i \alpha_{iT} = 0 \quad i, j = L, K, F, M$$

17/ Though not globally concave, this cost function is concave at the point of approximation if the Hessian matrix $[\partial^2 C/\partial W_i \partial W_j]$ is negative semi-definite; or alternatively, if the matrix of Allen-Uzawa partial elasticities in the input prices. That is, an increase in an input price must lead to increased total cost, and the predicted cost shares must be non-negative at each data point. By Sheppard's lemma (Diewert, 1971), the corresponding cost share equations are

$$S_i = \alpha_i + \sum_j \alpha_{ij}\, lnW_j + \alpha_{iQ}\, lnQ + \alpha_{iT} \ln T \qquad (4)$$

$$i = L, K, F, M$$

where

$$S_i = \frac{\partial lnC}{\partial lnW_i} = \frac{W_i X_i}{C}, \qquad \sum_i S_i = 1$$

is the cost share and where X_i is the cost-minimizing derived demand for the *i*th input obtained by differentiating (3) with respect to the price of the *i*th input. The term α_{ij} is the response of the share of *i*th input to a proportional change in the price of the *j*th input. Consequently, if $\partial S_i/\partial lnW_j = \alpha_{ij} > 0$ ($\alpha_{ij} < 0$), then *i*th cost share increases (decreases) with an increase in the price of the *j*th factor.

The factor bias of technical change is manifested in the movement of cost shares over time.[18] Specifically, the parameter value of α_{iT} represents the bias of technical change with respect to the *i*th factor since $\alpha_{iT} = \partial S_i/\partial lnT = \partial^2 lnC/\partial lnW_i \partial lnT = \partial^2 lnC/\partial lnT \partial lnW_i = \alpha_{Ti}$. The underlying technical change is "neutral" if it leaves the equilibrium factor shares unchanged (i.e., $\alpha_{iT}=0$), and "biased" if it alters the factor shares holding factor prices constant (i.e., $\alpha_{iT} \neq 0$). The technology is said to exhibit "factor-using" bias if $\alpha_{iT} > 0$, and "factor-saving" bias if $\alpha_{iT} < 0$. It follows that if technical change involving the ith factor is factor-using (saving), an increase (decrease) in W_i will reduce (increase) technical change. This implies that neutral technical change increases the productivity with which all factors are used, whereas biased technical change increases the average productivity of some factor more than others.

The Allen-Uzawa partial elasticities of substitution (σ_{ij}) and the related cross input price elasticities $\epsilon_{ij} = \partial lnX_i/\partial lnW_j$ are calculated from (4) following (Binswanger, 1974). Their statistical significance is tested using the method suggested by Pindyck (1979).[19] The final characteristic of the cost structure considered here is the returns to scale.[20] Since returns to scale are defined by the shape of the average cost curve, a natural measure of the scale economies is the reciprocal of the elasticity of the cost with respect to output. Using the dual cost function (3), we estimate the returns to scale as

$$RTS = \mathcal{E}_{CQ}^{-1} = [\frac{\partial lnC}{\partial lnQ}]^{-1} \qquad (5)$$

$$= \left[\alpha_Q + \alpha_{QQ} lnQ + \textstyle\sum_i \alpha_{iQ}\, lnW_i + \alpha_{QT}\, lnT \right]^{-1}$$

If the returns to scale are increasing (decreasing), the elasticity of costs with respect to output is less than (greater than) one, and conventional measures of TFP growth overestimate (underestimate) the effects of technical change. When returns to scale are constant, total cost and output increase at the same rate, i.e., RTS=1.

Data, Estimation Procedure and Results

The estimated models consists of two sets of share equations (one for "all utilities" and one for "private utilities") with each giving the shares of the four inputs in the value of output and the rate of technical change as functions of relative prices and time. The model is estimated on annual time series data for the period 1956-1991 for the Province of Newfoundland. The data come from Statistics Canada (Cat. #57-202) and the Newfoundland Statistics Agency and consist of sectoral observations for the output and four input aggregates for "private utilities," "public utilities," and "total utilities" (private plus public). Although significant investment in what were to become public sector facilities had taken place prior to 1967 as indicated above, commercial public sector generation did not begin until that time. But by combining data series for the aggregations "all utilities" and "private utilities" we generate two separate data sets spanning the period of interest 1956-

of substitution is negative semi-definite (Appendix A).

18/ Note that the share equations allow for both non-homotheticity and non-neutral technical change. The underlying technology is homothetic if $\sum_i \alpha_{iQ}=0$ for all *i*.

19/ See Appendix A.

20/ Note that Equation (3) permits the production structure to have any degree of returns to scale.

91.

The electric industry is highly heterogeneous. However, hydroelectric generation accounted for more than 88% of installed generating capacity during the sample period. About 99% of provincial hydro power is generated by "private utilities" and "public utilities" as defined by Statistics Canada.[21] Our data thus represent hydroelectric generation plants, albeit of various sizes.[22] The four input categories are labour, capital, fuel, and material. The data on labour measures man-hours employed. Total employee expenses were divided by total man-hours employed in order to obtain an implicit price index of labour services in each sector. To resolve the difficulty of determining the price of capital when equipment is not rented, we elected to use the Net Asset Approach employed by Daly and Rao (1985) and others. The capital stock is defined as the sum of total assets minus current liabilities. For the price of capital services, an opportunity cost of capital was calculated by dividing interest payments plus depreciation by net assets. This approach has the advantage of allowing sector-specific changes in the capital stock to be reflected through the depreciation rate.[23] The fuel input is an aggregate of four types of diesel oil.[24] Intermediate non-fuel material inputs represent the operation, administration and maintenance category. All prices deflated by the Consumer Price Index. Output, finally, is measured in kilowatt-hours of net generation by electric utilities, most of which are connected to the provincial power grid.

Sector-specific estimates are then obtained for the historical subperiods 1956-66, 1967-80, and 1981-91.[25] We follow the usual ad hoc practice (see, e.g., Binswanger, 1974), and assume an additive random error structure that satisfies Zellner's seemingly unrelated regression (SUR) model.[26] The model will have auto-correlated disturbances since the rate of technical change is not directly observable. The data were thus transformed to eliminate autocorrelation using a first-order autoregressive process.[27]

Several statistical tests can be performed to select the model that best represents the structure of production of electrical utilities. Since we have no reason to assume a priori that the underlying production technology is homothetic, the unconstrained model (4) assumes non-homotheticity and non-neutral technical change (i.e., $\alpha_{iQ}\neq0$ and

21/ The remainder is produced by "industries" not included in our sample. These are mostly small-scale hydro plants unconnected to the power grid, generating power primarily for internal use.

22/ The size of generation, transmission, and distribution facilities differ across firms, as does the technology and input-mix used. Unfortunately, separate data on generation, transmission and distribution are not available. Nor are data for the various generation technologies in use. Some cross-sectional data for Newfoundland and Labrador Hydro are available but commensurate data for the private sector are not. Like Daly and Rao (1985), we have to rely on time-series data since the insufficient plant or firm specific data on factor usage precludes pooling of data. Cf. Griffin (1977).

23/ This approach is not ideal but adequate for our purpose. The problem of capital measurement is well-known, notoriously difficult and has generated a large literature. For alternative approaches in the context of electric power generation, see Atkinson and Halvorsen (1980) and (1984).

24/ The Divisia index was used as an aggregation procedure, and the prices used were the implicit prices, i.e., the average cost per unit obtained by dividing total expenditure on a particular fuel grade by total quantity consumed. An index of fuel outlay was computed using the average price of the fuel grades used.

25/ The Chow (1960) test provides evidence for structural breaks in the data where postulated for both utility aggregations at the .05 level at least. The exceptions are fuel inputs for "all utilities," and capital inputs for "private utilities," the same variables/aggregations for which we report irregular input demand functions. The problem likely resides in both the data measurements and the model specification.

26/ With the cost function homogeneous of degree one in input prices the cost shares are homogeneous of degree zero and sum to unity. The error terms of the four share equations thus sum to zero, rendering the variance-covariance matrix singular. The equations are therefore not independent. This means that one equation must be dropped before the SUR procedure can be iterated to convergence. Berndt and Savin (1975) show that any equation can be dropped arbitrarily. The parameters of the deleted equation(s) can be estimated residually by invoking the assumptions of homogeneity and symmetry. When the convergence criteria (Dryhmes, 1971) are satisfied the values of the resulting estimates are asymptotically equivalent to maximum likelihood estimates. It should be noted that the estimates based on the share equations alone do not yield all the parameters of the cost function. The efficiency of the estimation may therefore improve were the cost function estimated jointly with the share equations. Unfortunately, the size of our data set does not allow this.

27/ Preliminary estimation yielded non-zero diagonal elements of the variance-covariance matrix of disturbance terms. To correct for this, we used the Cochrane-Orcutt iterative estimation method for models with AR(1) errors. Subsequent modified Durbin (1970) h-tests on the two aggregations indicate that no autocorrelation remain in the random disturbance terms.

$\alpha_{iT} \neq 0$). The first test is whether the cost structure is indeed non-homothetic translog since this matters as to whether the output variable needs to be included in the share equations.[28] When the null hypothesis is homothetic translog, it amounts to constraining the four α_{iQ} parameters to equal zero. The second test aims at checking whether the technological change exhibits any factor-bias (i.e., $\alpha_{iT}=0$). When the null hypothesis is homothetic translog with neutral technological change, all α_{iQ} and α_{iT} parameters are restricted to equal zero. To perform the tests, four versions of the same model were estimated for "private utilities" and "all utilities" respectively.[29]

Homotheticity

Table 4 presents the estimation results for the unconstrained model. For "private utilities," all parameter estimates are significant at the 5% level. For "all utilities," all but five parameter estimates are significant at the 5% level, two of which are significant at the 10% level. Of the six estimated α_{iQ} terms, five are significant at the 5% level and one at the 10% level. On the basis of these results, we reject the null hypothesis of an underlying homothetic technology in both utility sectors.

Technical Change

The effect of the estimated bias of technical change is indicated by the sign of the α_{iT} terms (Table 4). The parameters can be interpreted as changes in the sectoral value shares with respect to time, holding prices constant. This component can be attributed to changes in technology rather than to substitutions among inputs. Assuming non-homotheticity, all six α_{iT} coefficients are significant at the 5% level. We thus reject the null hypothesis of neutral technological progress for both "private utilities" and "all utilities." The average pattern of technological progress (1956-91) shows striking differences between the two aggregations of utilities. For "private utilities," technological progress was labour and fuel-saving, and capital and materials-using.[30] For "all utilities," the results again indicate labour-saving and materials-using bias, but now also capital-saving and fuel-using bias. The main difference between our findings and those commonly reported in the literature is the capital-using bias of technical change in private utilities.[31]

Table 4: Share Equation Estimates[a] for Private Utilities and All Utilities, 1956-91

Parameter	Private Utilities		All Utilities	
α_L	-0.5513*	(0.2845)	-0.2659	(0.2832)
α_K	1.6719*	(0.3520)	0.1932	(0.3886)
α_F	-1.3464*	(0.3461)	0.2612	(0.2376)
α_M	1.2258		0.8115	
α_{LL}	0.1096*	(0.0312)	0.0726*	(0.0263)
α_{LK}	-0.0495*	(0.0285)	-0.0586*	(0.0299)
α_{LF}	0.0128*	(0.0057)	-0.0337*	(0.0146)
α_{LM}	-0.0729*	(0.0143)	0.0197‡	(0.0130)
α_{KK}	0.2644*	(0.0551)	0.3992*	(0.0563)
α_{KF}	-0.2820*	(0.0563)	-0.1997*	(0.0338)
α_{KM}	0.0671*	(0.0236)	-0.1409*	(0.0318)
α_{FF}	0.3062*	(0.0648)	0.0969*	(0.0300)
α_{FM}	-0.0369*	(0.0197)	0.1365*	(0.0201)
α_{MM}	0.0427		-0.0154	
α_{LQ}	-0.0211*	(0.0084)	-0.0107‡	(0.0074)
α_{KQ}	0.0087*	(0.0033)	0.1091*	(0.0178)
α_{FQ}	0.0208*	(0.0202)	-0.0222*	(0.0127)
α_{MQ}	-0.0084		-0.0762	
α_{LT}	-0.0471*	(0.0114)	-0.0608*	(0.0115)
α_{KT}	0.0655*	(0.0312)	-0.1933*	(0.0274)
α_{FT}	-0.0652*	(0.0340)	0.0984*	(0.0223)
α_{MT}	0.0468		0.1558	
R^2 Labour-share equation:	0.77		0.86	
R^2 Capital-share equation:	0.65		0.7	
R^2 Fuel-share equation:	0.79		0.9	

a) Asymptotic standard errors (in parentheses) are reported on account of the degrees of freedom afforded by the small sample size (N=36)

* significant at the .05 level

‡ significant at the .1 level

28/ See e.g., Takayama (1985:149).

29/ Only one set of estimates for each group is reported here. Three additional versions of (4) were estimated under the following assumptions respectively, $\alpha_{iQ}=0$; $\alpha_{iT}=0$; and $\alpha_{iQ}=\alpha_{iT}=0$. Based on significance testing, these models were inferior to the (non-homothetic) model reported in Table 4. All results are available from the authors upon request.

30/ The results suggest material-using bias for both sectors although no standard error for the two α_{MT} terms can be reported.

31/ Variations in the pattern of factor bias in the litera-

Elasticities of Substitution

The estimated substitution elasticities (Tables B1 and B2 in Appendix B) indicate the existence of pair-wise substitution possibilities between all four input with the attendant implications for the distribution of the value of the output among the inputs. The Allen-Uzawa elasticities of substitution show that for both sectors (1956-91), fuel and materials are substitutes, and capital and fuel are complements.[32] For "private utilities" labour and fuel, and capital and materials are substitutes (Table B1). Labour and materials are complements. The reverse is true for the latter two of these combinations for "all utilities" (Table B2). The estimates for the three subperiods are largely consistent with those for the entire period 1956-91, suggesting that the additions and transfers of productive capacity between the private and public sectors of the utilities industry in these subperiods do not invalidate our model specification.

Elasticities of Input Demand

The regularity conditions required by cost-minimizing behaviour impose curvature restrictions on the production function: the diagonal terms (Tables B3 and B4) must be negative, i.e., all own-price elasticities $\in_{ii}$ must be negative. Comparing the factor demand structures for the two aggregations we find that for "all utilities" (Table B3), all $\in_{ii}$ terms except fuel have the expected sign. Also, the capital term is not significantly different from zero. Again, the estimates for the entire period are supported by those for the various subperiods. For "private utilities" (Table B4) all $\in_{ii}$'s except that of capital have the expected negative sign.

If our model is in fact correctly specified, then one explanation for these findings is the (implicit) assumption of negligible differences between ex-ante expected and ex-post realized prices of capital. However, if expectations are not realized regarding the purchase and disposal prices of non-adjustable inputs, future interest rates, tax rates and depreciation rates, the ex-ante user cost can differ significantly from the ex-post user cost observed from accounting data.[33] It is thus possible that our capital cost measures do not reflect the real (unsubsidized) cost of capital employed.

Another explanation centres on a short-run/long-run distinction involving a variable that is not in our model, installed capacity.[34] Although the price of capital is sensitive to wasteful duplication of facilities, investment in capacity is essentially a function of expected future demand for electricity. The cost is sunk once the capacity is installed: further capital expenditure will depend more on the size of installed capacity and less on its price, whereas capacity usage depends on current demand. However, the most likely explanation for the unexpected sign of $\in_{KK}$ for private utilities relates to the capital-using factor-bias in that sector. We attribute this to the massive transfer of capacity from the private sector to the public sector followed by a negative growth rate in capital expenditures (-1.29%) in the critical 1967-80 period.

The counterintuitive sign of the fuel price elasticity coefficient may be related to the fuel procurement practices of some electric utilities. Weak incentives for least-cost procurement have been linked to automatic adjustment clauses although the evidence appears mixed.[35]

Returns to Scale

In calculating returns to scale for the period 1956-91 an interesting difference is observed for the two aggregations of utilities (Table 5): "private

ture stem, in part, from the number of inputs considered. Gollop and Roberts (1981) report K-neutral, L-saving, and F-using bias; Gollop and Roberts (1983) and Stevenson (1980) report F-using, and L and K-saving bias; Nelson (1986) report estimates for three time periods: first, K-saving, and F-using bias; second, F-using; and third, L and K-using, and F-saving bias; Jorgensen and Fraumeni (1983) report K, M and L-saving, and F-using bias; Daly and Rao (1985) report K and L-saving, and F and M-using bias.

32/ Baily (1981) also finds K-F complementarity, but Daly and Rao (1985) report K-F substitutability. For a discussion of the controversy in the literature regarding the complementarity of capital and energy, see Berndt and Wood (1979).

33/ See Diewert (1991) and the references contained in this paper.

34/ The R^2 of the K-share equation is lower. However, inclusion of capacity utilization would result in multicollinearity. We note that Daly and Rao (1985) found that their empirical results were not materially affected when capacity utilization was omitted from their cost function.

35/ See Joskow and Schmalensee (1983).

utilities" exhibit decreasing returns to scale on average, while "all utilities" exhibit increasing returns to scale. Our results indicate that a 10% increase in output would result in an 8.3% increase in total cost for "all utilities," and a 12.4% increase for "private utilities."[36] By previous argument we infer that the estimate for "all utilities" underestimates the degree of scale economies in the public sector proper. This would imply scale economies for public utilities comparable with the range .45-.55 reported for Ontario Hydro by Daly and Rao (1985). The most surprising finding is the existence of diseconomies of scale in private utilities.[37] We have no reason a priori for expecting sectoral differences in the extent to which capital embody exploitation of scale economies. An interpretation consistent with the factor-bias reversals is that the scale estimates reflect different patterns of learning how best to exploit scale economies.[38] This could affect, for example, how long capacity was installed before technical change produced the economies, or the extent to which investment in (public sector) plants smaller than minimum efficient size would continue. It is also plausible that the legal constraints on the export of electricity from Newfoundland[39] combine with a local market for electricity that is simply not large enough to fully exploit existing scale economies.

Table 5: Estimated Effects of Scale on Costs[1] in Private Utilities and All Utilities, 1956-91

Parameter	All Utilities	Private Utilities
ϵ_{CQ}	0.8263* (0.002)	1.2442* (0.0123)

1/ Asymptotic standard errors in parentheses.
* significant at .01 level using a one-tailed test.
Note: H_0: $(1-\epsilon_{CQ}) > 0$

Discussion and Conclusions

By summarizing key results from the accounting approach and the econometric model (Table 6) we uncover structural differences and changes in input demand between ownership categories. In what follows reference is made to public utilities rather than "all utilities" as in the previous discussion. The entries for the public sector are derived from the results presented. From the known characteristics of the total electric utility industry and those of the private sector, certain public sector characteristics of interest can be inferred.[40] Table 6 suggests that fuel-capital relationships, and fuel-material relationships are uniform across sectors; the factors are complements and substitutes respectively. Materials-labour relationships are not uniform across sectors: the factors are substitutes for public utilities, and complements for private utilities. The reverse holds for the materials-capital relationships: the inputs are complements for public utilities and substitutes for private utilities.[41]

This flip-flop between complementarity and

36/ These estimates are somewhat higher than most electric utility scale estimates reported in the literature. For example, Nelson (1990b) estimates the ϵ_{CQ} at .9431; Gollop and Roberts (1981) report a range: .68-.9, as do Nelson and Wohar (1983): .9274-.9672, and Neuberg (1977): .9539-.9878. Joskow (1987) reports scale economies in generation; Christensen and Greene (1976) find that most utilities in their sample exhibit scale economies, but the larger firms supplying most of the output show only minimal scale economies. Although most studies find scale economies at the plant level, it is not clear how important they are, at what level they are exhausted, or how they derive from unit- or multi-unit economies (Joskow and Schmalensee, 1983). Transmission capabilities transform scale economies at the plant level into economies at the system-level, but in almost all cases, data limitations make it impossible to distinguish empirically estimates of scale economies at the generation-level from system-level economies.

37/ It should be cautioned that in highly trended time series the elasticity of scale and the rate of technical change are generally correlated, and the latter, therefore is difficult to identify unambiguously (Fuss and Waverman 1981). Consequently, our estimates of technical progress and returns to scale may be biased downwards and upwards respectively.

38/ For example, Rose and Joskow (1990) show that large firms and investor-owned utilities are likely to adopt new technology earlier than their public sector counterparts.

39/ This refers to the infamous 1969 deal signed by the then-Premier Smallwood to secure critical financing of the 5,200 MW Churchill Falls hydro development in exchange for a promise to sell to Quebec until 2041 all but a maximum local 350MW allotment at a nominal rate of 0.25¢/kWh.

40/ This means that the qualitative entries for "public utilities" will be the same as those for "all utilities," except where the corresponding private sector characteristic is not known with confidence as indicated by a question mark in the cell in question.

41/ Thus an explanation based on a short-run/long-run distinction with reference to our findings of scale economies does not seem to apply. Intuitively, a lack of flexibility in material-labour and capital relationships in the short-run would tend to induce complementarity; greater flexibility in the long run would tend to induce substitutability.

Table 6: Summary of Results by Sector: Relative Factor Cost Growth, Relative Partial Factor Productivity Growth, Factor Bias, Elasticity of Input Demand, Substitutability, and TFP Growth, 1956-91

	Public Utilities				Private Utilities			
Factor:	L	K	F	M	L	K	F	M
Relative Factor Cost Growth	High	High	High	High	Low	Low	Low	Low
Relative Partial Factor Productivity Growth	High(>0)	High(>0)	High(>0)	High(>0)	Low(>0)	Low(<0)	Low(<0)	Low(>0)
Factor-bias	Saving	Saving	Using	Using	Saving	Using	Saving	Using
Elasticity of Demand	<0	?	>0	<0	<0	>0	<0	<0
L		?	?	Subst.		?	Subst.	Compl.
K			Compl.	Compl.			Compl.	Subst.
F				Subst.				Subst.
Total Factor Productivity Growth		>0				<0		

Subst.=Substitutes; Compl.=Complements

substitutability reflect key differences across sectors, which when viewed together with the pattern of factor-bias have implications for the relationship between relative prices and the sectoral growth rates. In the public sector the factor-bias is fuel and materials-using and capital-saving. We argue that increases in the relative prices of materials and fuel since the mid 1970s lead to a premature obsolescence of capital which in turn contributed to a reduction in capacity utilization.[42] This would imply that fuel and capital, and material and capital are complements (which we find them to be). The patterns of factor complementarities and bias just noted would both slow the rate of technological progress in this situation. This could explain our findings of falling PFP and TFP growth rates, a result consistent with those for the United States reported by Baily (1981), and Nelson and Wohar (1983).

Counteracting this downward pressure on TFP growth is the presence of scale economies. The labour-saving bias and high growth of the PFP of labour increased the rate of technical change in the face of higher input costs. The net effect of the above mentioned forces rendered the TFP growth rate positive for public electric utilities in the earlier phases of industrial development.[43] The decline in TFP in the public sector in more recent times is likely attributable, at least in part, to the growth rate in real labour costs (Table 3) and unit labour costs (both of which were considerably higher in the public sector).

Moreover, differences in unit labour costs across sectors may help explain the observed inter-sector difference in the patterns of capital usage. Although we were unable to estimate the K-L input relationship from our data and model it appears that K-saving technical change in the public sector is associated with increasing expenditure on capital (and thus possibly substitution of capital for labour.) This might be the result of a capital subsidy or the relatively higher unit labour cost in the public sector during the period.[44]

Turning to the private sector, technological progress unlike that in the public sector shows capital and materials-using (and fuel-saving) factor bias. Given the fuel-capital complementarity, rising fuel prices will cause premature obsolescence of capital. Capacity usage will fall on this account. The rate of technical change will in turn slow, implying falling PFP and TFP growth rates as well.

The factor bias of private utilities is also materials-using. That is, as the price of materials increase, technical progress slows. But since materials and capital are substitutes in this case, capacity usage increases, ceteris paribus. While the over-all effect is a fall in capacity usage, it is seen to fall less rapidly than in the public sector. (The negative growth rate in the expenditure on capital

42/ Admittedly, the fuel-using bias is less important since the production capacity consists overwhelmingly of hydroelectric facilities.

43/ Daly and Rao (1985) also find falling but positive TFP growth for Ontario Hydro but for different reasons.

44/ This was noted by a referee.

also suggests that capacity remaining after the asset transfer in the 1967-80 was used relatively more intensively amongst private utilities.) The failure of the private sector to subsequently expand the capital stock may again be attributable to a competitive disadvantage in terms of capital subsidies vis-à-vis the public sector. This would help explain our empirical finding that scale economies are now exhausted in the private sector. Taken together, our results suggest that the diseconomies of scale in private utilities, the fall in private sector output, and the falling rates of technical change all contributed to the negative TFP growth in private electric utilities during the period under study.

In sum, this paper has investigated inter-sectoral differences in productivity growth and production structure of electrical utilities in Newfoundland during 1956-91. Drawing on evidence from both an accounting framework and a translog cost function approach we find that the production structure is non-homothetic and characterized by biased technical change. Our results are preliminary but suggest that electric power is not supplied at least cost in Newfoundland, although differences across ownership categories are discovered.

Results that are consistent with cost minimizing behaviour on the part of public electric utilities indicate that increases in the price of labour, fuel and intermediate non-fuel materials would put downward pressure on the level of output. An expansion of output at constant factor prices would lead to declining average cost due to substantial economies of scale. In the private sector, increases in the price of labour and materials and fuel would put downward pressure on the level of output. But in this sector an expansion of output at constant factor prices would lead to a higher average cost due to diseconomies of scale. These efficiency findings are associated with inter-sector variations in the patterns of factor bias of technical progress, factor complementarity, and factor productivity. What accounts for the differences in cost savings between sectors? With both sectors exhibiting labour and materials-using technical change, we conjecture that the relative cost savings in the public sector was achieved through capital-saving technical change. By itself this finding does not support the hypothesis that investor-owned utilities are more cost efficient than publicly owned utilities. Moreover, the present concentration of the industry combined with almost perfect capital immobility are characteristics that resist competitive market forces released as a result of government divestiture. On the basis of the results reported in this paper it is not clear that privatization, ceteris paribus, would improve productive efficiency in the electric utility industry in Newfoundland. An objective evaluation of the merits of public versus private ownership requires better measurement of capital prices and in particular, an analysis of regulatory practices, output pricing, and sector-specific subsidization of capital and labour. These issues are beyond the scope of the present paper, in part because some of the data required were not available to us at the time this study was undertaken.

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Appendix A

The Allen-Uzawa elasticities of substitution are

$$\sigma_{ij} = \frac{(\alpha_{ij} + S_i S_j)}{S_i S_j} \quad for\ i \neq j \qquad \text{and} \qquad \sigma_{ii} = \frac{(\alpha_{ii} + S_i^2 - S_i)}{S_i^2} \quad for\ i = j$$

If $\sigma_{ij} > 0$ ($\sigma_{ij} < 0$) for $i \neq j$, then the inputs i and j are substitutes (complements) in production. If the cost function is Cobb-Douglas, then $\alpha_{ij} = 0 = \alpha_{iQ}$ in (4). This implies in turn that $\sigma_{ij} = 1$. Using the above expressions the cross input price elasticities can be calculated as

$$\varepsilon_{ij} = S_j \sigma_{ij} \quad for\ i \neq j \qquad \text{and} \qquad \varepsilon_{ii} = S_i \sigma_{ii} \quad for\ i = j$$

Intuitively, the percentage change in variable input i caused by a percentage change in the *j*th input price is equal to the technical substitution possibility between inputs *i* and *j* weighted by the *j*th variable input's share in cost. The partial substitution elasticities are symmetric by Young's theorem, unlike the input price elasticities ($\epsilon_{ij} \neq \epsilon_{ji}$). To test for statistical significance we hold the cost shares S_i constant at their means over the sample period and obtain the asymptotic variances of the elasticities of substitution (Pindyck, 1979) as:

$$Asy.var(\sigma_{ij}) = \frac{Asy.var(\alpha_{ij})}{S_i^2 S_j^2} \quad for\ i \neq j$$

$$Asy.var(\sigma_{ii}) = \frac{Asy.var(\alpha_{ii})}{S_i^4} \quad for\ i = j$$

Similarly, the asymptotic variance of the elasticities of factor demand are computed as

$$Asy.var(\varepsilon_{ij}) = \frac{Asy.var(\alpha_{ij})}{S_i^2}, \quad for\ i \neq j$$

$$Asy.var(\varepsilon_{ii}) = \frac{Asy.var(\alpha_{ii})}{S_i^2}, \quad for\ i = j$$

Appendix B

Table B1: Estimated Allen-Uzawa Partial Elasticities of Substitution[1] for Private Utilities

Parameter	1956-1966 Estimate	1967-80 Estimate	1981-91 Estimate	1956-91 Estimate	
σ_{LL}	-1.25	-1.07	-0.52	-1.19	(0.95)
σ_{KK}	0.06	0.83	2.99	0.17	(0.36)
σ_{FF}	23.23	2.57	0.19	1.23	(0.79)
σ_{MM}	-3.91	-3.66	-4.47	-3.98	
σ_{LK}	0.61	0.35	-0.86	0.31	(0.40)
σ_{LF}	1.53	1.34	1.17	1.24*	(0.11)
σ_{LM}	-1.07	-1.78	-3.58	-1.86*	(0.56)
σ_{KF}	-4.66	-1.77	-1.66	-1.52*	(0.50)
σ_{KM}	1.92	1.96	4.06	2.23*	(0.43)
σ_{FM}	-1.67	-0.05	0.42	0.08	(0.50)

Note: Estimated at the mean level of observation.

1/ Asymptotic standard errors in parentheses for 1956-91. The standard errors for the sub-periods cannot be calculated since the α_{ij} terms are constant for the period 1956-91 (cf. Caves *et al.*, 1981).

* significant at .05 level

Table B2: Estimated Allen-Uzawa Partial Elasticities of Substitution[1] for All Utilities

Parameter	1956-1966 Estimate	1967-80 Estimate	1981-91 Estimate	1956-91 Estimate	
σ_{LL}	-1.92	-2.37	-2.44	-2.29*	(0.78)
σ_{KK}	0.61	0.79	1.77	0.88*	(0.32)
σ_{FF}	1.47	-1.58	-1.16	-1.57*	(0.73)
σ_{MM}	-5.23	-4.50	-4.19	-4.59	
σ_{LK}	0.50	0.21	-0.24	0.24	(0.39)
σ_{LF}	-0.52	-0.03	0.30	0.10	(0.39)
σ_{LM}	1.47	1.60	1.64	1.56*	(0.37)
σ_{KF}	-3.35	-1.33	-0.92	-1.34*	(0.40)
σ_{KM}	-0.63	-0.63	-1.13	-0.74*	(0.39)
σ_{FM}	9.41	4.57	3.03	4.48*	(0.51)

Note: Estimated at the mean level of observation.

1/ Asymptotic standard errors in parentheses for 1956-91. See also the note to Table B1.

* significant at .05 level

Table B3: Estimated Own- and Cross-Price Elasticities of Input Demand[1] for All Utilities

Year	Input:	Labour		Capital		Fuel		Material	
1956-1966	Labour	-0.31		0.15		0.38		-0.26	
	Capital	0.31		0.03		-2.39		0.98	
	Fuel	0.14		-0.45		2.25		-0.16	
	Material	-0.15		0.27		-0.24		-0.56	
1967-1980	Labour	-0.18		0.06		0.22		-0.30	
	Capital	0.16		0.04		-0.80		0.88	
	Fuel	0.30		-0.40		0.58		-0.01	
	Material	-0.28		0.30		-0.01		-0.57	
1981-1991	Labour	-0.07		-0.12		0.16		-0.50	
	Capital	-0.16		0.57		-0.32		0.78	
	Fuel	0.65		-0.92		0.11		0.23	
	Material	-0.41		0.47		0.05		-0.51	
1956-1991	Labour	-0.22	(0.17)	0.06	(0.16)	0.23*	(0.03)	-0.34*	(0.08)
	Capital	0.12*	(0.07)	0.07	(0.14)	-0.59*	(0.14)	0.31*	(0.17)
	Fuel	0.36*	(0.02)	-0.44*	(0.20)	0.35*	(0.23)	0.01	(0.14)
	Material	-0.26*	(0.10)	0.31*	(0.17)	0.01	(0.14)	-0.55	

Note: Estimated at the mean level of observation.
1/ Asymptotic standard errors in parentheses. See note to Table B1.
* significant at .05 level

Table B4: Estimated Own- and Cross-Price Elasticities of Input Demand[1] for Private Utilities

Year	Input:	Labour		Capital		Fuel		Material	
1956-1966	Labour	0.46		0.12		0.12		0.35	
	Capital	0.25		0.30		-1.66		0.31	
	Fuel	0.05		0.31		0.14		0.87	
	Material	0.26		0.11		1.64		0.91	
1967-1980	Labour	0.40		0.04		0.01		0.27	
	Capital	0.9		0.35		0.59		0.28	
	Fuel	0.1		0.26		0.31		0.89	
	Material	0.31		0.12		0.89		0.88	
1981-1991	Labour	0.36		0.04		0.04		0.24	
	Capital	0.08		0.57		0.29		0.36	
	Fuel	0.10		0.30		0.38		0.98	
	Material	0.34		0.23		0.63		0.87	
1956-1991	Labour	0.42*	(0.14)	0.04	(0.16)	0.02	(0.08)	0.29*	(0.07)
	Capital	0.11*	(0.07)	0.37*	(0.13)	0.56*	(0.08)	0.31*	(0.08)
	Fuel	0.02	(0.07)	0.27*	(0.17)	0.32*	(0.15)	0.91*	(0.10)
	Material	0.30*	(0.07)	0.14	(0.16)	0.86*	(0.10)	0.89	

Note: Estimated at the mean level of observation.
1/ Asymptotic standard errors in parentheses. See note to Table B1.
* significant at .05 level