Predicting Growth in SPI's O&M Expenses

Pacific Economics Group, LLC
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1. INTRODUCTION AND SUMMARY

1.1 Introduction

Victoria's Essential Services Commission ("ESC" or "Commission") is updating its price control system for electricity distribution businesses ("DBs"). The current system expires on 31 December 2005. Last June, the ESC issued a final "Framework" document that details the approach it will use for the update and provides guidance to DBs for the preparation of their revenue, tariff, and service proposals.[1]

According to the Framework, the ESC will once again use price control indexes that are designed using a "building block" approach. Under this approach, the price control mechanism is expected to recover the target cost of service during the (five year) plan period. The target cost of service is constructed from targets for important cost components such as operation and maintenance expenditures ("opex"), capital expenditures, and depreciation.

The ESC intends to use a "rate of change" approach to determine opex targets. Under this approach, the Commission will recognize as base levels of opex those incurred by the DBs in 2004.

> The Commission considers that it can rely on the incentive properties of the CPI-X framework, with an efficiency carryover mechanism, to provide incentives for distributors to achieve efficiencies in operating and maintenance expenditure...the Commission can infer that reported actual costs are efficient.[2]

Its focus is thus on acceptable rates of growth in opex.

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[1] Essential Services Commission, *Electricity Distribution Price Review 2006 Final Framework and Approach*, June 2004.

[2] *ibid*, p. 66.

Opex in 2006, the first year of the new price control period, will equal the actual level incurred in 2004 with an adjustment for "the annual efficiency gain implied by the original forecasts for the years 2004 and 2005" and "any improvement in efficiency the Commission considers appropriate between the years 2005 and 2006 having regard to experience to date in the current regulatory period and any other relevant considerations."[3] With regard to the out years of the next regulatory period, the Commission proposes to base its estimate on the 2006 expenses thus calculated plus a growth factor.

> The rate of change is defined as the year to year change in operating and maintenance expenditure reflecting a number of factors such as, expected productivity improvements and changes in the price of distributor inputs. The Commission proposes to add on an explicit allowance for the cost of serving additional customers.[4]

Distributors are invited to propose appropriate input price and productivity adjustments. Additionally,

> The Commission will require distributors to propose the additional operating costs incurred to serve new customers (on a dollar per customer basis). The Commission considers this would relate primarily to customer service and billing and revenue collection.[5]

The language suggests that the Commission expects the rate of change proposal of the DBs to pertain to inflation and productivity issues but not to the customer growth issues.

As the Commission notes, there is some precedent for this general approach to establishing opex targets in its 2002 review of the Victorian gas access arrangements.[6] The Commission in that review assumed that the target opex of all four jurisdictional gas distributors would decline in real terms by 1% per annum. This is the average of the real growth trends in the opex proposals of the four distributors. It is, additionally, similar to the net allowances for base productivity growth and output growth in prior decisions on

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[3] *ibid*, p. 68.
[4] *ibid*, p. 68.
[5] *ibid*, p. 68.
[6] ESC, *Review of Gas Access Arrangements: Final Decision*, October 2002.

gas distributor opex growth by the Queensland Competition Authority and the Independent Pricing and Regulatory Tribunal in New South Wales.

Pacific Economics Group, LLC ("PEG") is the world's leading provider of energy industry productivity studies. Senior author and project leader Mark Newton Lowry has testified fourteen times on productivity issues. The Company has retained us to use our research methods to design an appropriate opex growth factor for SPI.

This is the report on our work. In the next section we develop a logical framework for making opex projections. There follows a discussion of relevant regulatory precedents. Highlights of our empirical work are presented in Section 4. Further details of the research are furnished in the Appendix.

1.2 Summary

1.2.1 Analytical Framework

We demonstrate using mathematical reasoning that the growth rate of a distributor's opex can be decomposed into the growth rate in an input price index less the growth rate in a productivity index plus the growth rate in an output quantity index.[7] This important result provides the basis for predicting opex using a three-step indexing method. The first step is the prediction of input price growth. The second is the prediction of productivity growth. It is generally reasonable to use for this purpose the recent historical productivity trend of the industry. The third step is the prediction of output quantity growth.

The discussion also provides useful insights on the nature of productivity growth. For example, we show that economies of scale are one of the basic sources of productivity growth. Any scale economies realized by the industry during the sample period used for productivity research will therefore bolster the measured trend in the productivity index. Furthermore, there is no need to adjust the rate of output growth for scale economies when predicting opex growth. Any such adjustment will, effectively, double count the impact of scale economies on opex growth. It follows that if the impact of output growth is to be discounted for scale economies, the measure of productivity growth should be modified to exclude scale economies.

We also show that the pace of productivity growth depends in part on the rate at which a firm reduces or increases its inefficiency and thereby moves towards or away from the production frontier made possible by current technology. It follows that the privatization of utilities can, by increasing the incentives for prudent cost management, cause a temporary acceleration in productivity growth as firms move closer to the efficiency frontier. When projecting future productivity growth, this reduces the usefulness of operating data from utilities that have recently become investor-owned businesses subject to price control regulation.

1.2.2 Regulatory Precedents

Productivity indexing is extensively used in North American utility regulation. Precedents established there are useful for appraising the appropriateness of our proposed method. Indexes designed to establish revenue requirements or components thereof are especially valuable because they require output growth allowances. We identify four price control plans in which revenue requirement indexes feature input price, productivity, and output growth components. In all four cases the number of customers served was the output growth measure and the full rate of customer growth determined the output growth allowance.

1.2.3 Empirical Research

Our analysis in Section 2 lead us to compute the appropriate productivity adjustment using recent historical data for a sample of investor-owned U.S. electric power distributors. Quality data are available in the States for more than seventy distributors for a period of more than ten years. None of these distributors was recently privatized and few have been subject to formal price control regulation.

We calculated industry productivity trend indexes for O&M inputs and for total inputs over the 1993-2003 sample period. The sample included data for 77 distributors.

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[7] Analogous results exist for total cost.

The year 2003 is the most recent for which the required data are available. We found that over this period the productivity of O&M inputs averaged 0.82% annual growth. The total factor productivity of the aggregate averaged 0.69% annual growth.

Our measures of output quantity growth were chosen on the basis of econometric cost research. The evidence suggests that the total cost of power distributors depends chiefly on the number of customers served but also depends on delivery volumes. Our research on opex, however, permitted us to identify only one output quantity variable: the number of customers served. Our econometric opex research also showed that the typical U.S. distributor in the sample realized considerable economies of scale. The realization of scale economies was thus an important source of productivity growth during the sample period.

We also predicted input price and output quantity growth over the 2006-2010 period for SPI using data obtained from the company. The number of customers is predicted to grow at a 1.99% annual rate. Using data provided by SPI, we also predict 3.82% average annual growth in the prices of O&M inputs. It follows that the opex of SPI is likely to grow at a 4.99% average annual rate in nominal terms. Assuming the escalation mechanism for target opex uses the consumer price index (CPI) as an inflation measure, the evidence suggests that the mechanism should permit opex to grow 2.43% more rapidly each year than the CPI.

2. ANALYTICAL FRAMEWORK

In this section we provide a logical framework for the analysis of growth in O&M expenses. We begin with a review of the relevant mathematical theory. There follows a discussion of practical applications.

2.1 Theoretical Results

2.1.1 Cost Growth

The starting point for the analysis is the assumption that the O&M expenses incurred by a firm is the product of the minimum attainable expenses, C_{OM}^{*}, and a term, η, that may be called the inefficiency factor.

$$C_{OM} = C_{OM}^{*} \cdot \eta . \qquad [1]$$

The inefficiency factor indicates how high the actual expenses of a firm are above the minimum attainable level.

It is a basic result of economic theory that given a well-behaved production technology, the minimum attainable level of O&M expenses is a function of vectors of the prices of O&M inputs ($\boldsymbol{W} = W_1, W_2 \ldots W_J$), output quantities ($\boldsymbol{Y} = Y_1, Y_2 \ldots Y_I$), capital quantities ($\boldsymbol{X_K} = X_{K,1}, X_{K,2} \ldots X_{K,M}$), and variables that measure miscellaneous other relevant business conditions ($\boldsymbol{Z} = Z_1, Z_2 \ldots Z_N$). The inclusion of a trend variable (T) indicates that the function may shift over time due to technological change. The resultant short run cost function can be represented mathematically as

$$C_{OM}^{*} = g(\boldsymbol{W}, \boldsymbol{Y}, \boldsymbol{X_k}, \boldsymbol{Z}, T). \qquad [2]$$

Notice that the theory allows for the existence of more than one output related cost driver. In the Final Framework, however, the ESC appears to assume that there is only one relevant output quantity variable, the number of customers served.

Consider now that if we use calculus to totally differentiate Equation [2] with respect to time it can be shown that

$$\dot{C}^*_{OM} = \left(\sum_i \varepsilon_{Y_i} \cdot \dot{Y}_i + \sum_j \varepsilon_{W_j} \cdot \dot{W}_j + \sum_m \varepsilon_{X_{K,m}} \cdot \dot{X}_{K,m} + \sum_n \varepsilon_{Z_n} \cdot \dot{Z}_n \right) + \dot{g}. \qquad [3]$$

Equations [1] and [3] imply that the growth rate of *actual* (not minimum) cost is then given by

$$\dot{C}_{OM} = \left(\sum_i \varepsilon_{Y_i} \cdot \dot{Y}_i + \sum_j \varepsilon_{W_j} \cdot \dot{W}_j + \sum_m \varepsilon_{X_{K,m}} \cdot \dot{X}_{K,m} + \sum_n \varepsilon_{Z_n} \cdot \dot{Z}_n \right) + \dot{g} + \dot{\eta}. \qquad [4]$$

The term ε_{Y_i} in equation [4] is the elasticity of cost with respect to output i. It measures the percentage change in cost that is due to a small percentage change in the output. The other ε terms have analogous definitions. The growth rate of each output quantity i is denoted by $\dot{Y}_i$. The growth rates of the other business condition variables are denoted analogously.

The growth rate of O&M expenses is thus the sum of three terms. The first is the sum of the products of the growth rates of each business condition variable and the corresponding cost elasticity. The impact on cost of customer growth, for example, depends on the rate of customer growth and the elasticity of cost with respect to customer growth. The second term is the shift in the cost function ($\dot{g}$) over time. The third term is the growth rate of the inefficiency factor.

An important result of cost theory, Shephard's lemma, holds that the derivative of minimum cost with respect to the price of an input is the optimal input quantity. The elasticity of minimum cost with respect to the price of each input *j* can then be shown to equal the optimal share of that input in minimum cost (SC^*_j). Equation [3] may therefore be rewritten as

$$\begin{aligned} \dot{C}_{OM} &= \sum_i \varepsilon_{Y_i} \cdot \dot{Y}_i + \sum_j SC^*_j \cdot \dot{W}_j + \sum_m \varepsilon_{X_{K,m}} \cdot \dot{X}_{K,m} + \sum_n \varepsilon_{Z_n} \cdot \dot{Z}_n + \dot{g} + \dot{\eta}. \\ &= \sum_i \varepsilon_{Y_i} \cdot \dot{Y}_i + \dot{W}^*_{OM} + \sum_m \varepsilon_{X_{K,m}} \cdot \dot{X}_{K,m} + \sum_n \varepsilon_{Z_n} \cdot \dot{Z}_n + \dot{g} + \dot{\eta}. \end{aligned} \qquad [5]$$

The second term on the right-hand side of the equation is the growth rate of an O&M input price index, which we denote by W^*_{OM}. The growth rate of W^*_{OM} is a weighted average of the growth rates in the price subindexes for each input category. The *optimal* (cost-minimizing) cost shares serve as weights. We will call W_{OM}^{*} the optimal input price index.

Consider, next, that by multiplying the numerator and the denominator of the first term in [5] by the sum of the output-related cost elasticities $\left(\sum_i \varepsilon_{Y_i}\right)$ we obtain

$$\begin{aligned}\dot{C}_{OM} &= \sum_i \varepsilon_{Y_i} \cdot \sum_i \left(\varepsilon_{Y_i} / \sum_i \varepsilon_{Y_i}\right) \cdot \dot{Y}_i + \dot{W}_j^* + \sum_m \varepsilon_{X_{K,m}} \cdot \dot{X}_{K,m} + \sum_n \varepsilon_{Z_n} \cdot \dot{Z}_n + \dot{g} + \dot{\eta}. \\ &= \sum_i \varepsilon_{Y_i} \cdot \dot{Y}^{\varepsilon} + \dot{W}_{OM}^* + \sum_m \varepsilon_{X_{K,m}} \cdot \dot{X}_{K,m} + \sum_n \varepsilon_{Z_n} \cdot \dot{Z}_n + \dot{g} + \dot{\eta}\end{aligned}$$

and

$$\begin{aligned}\dot{C}_{OM} &= \sum_i \varepsilon_{i\ Y_i} \cdot \dot{Y}^{\varepsilon} + \dot{W}^* + \sum_m \varepsilon_{X_{K,m}} \cdot \dot{X}_{K,m} + \sum_n \varepsilon_{Z_n} \cdot \dot{Z}_n + \dot{g} + \dot{\eta} + \dot{Y}^{\varepsilon} - \dot{Y}^{\varepsilon} \\ &= \dot{W}_{OM}^* + \dot{Y}^{\varepsilon} - (1 - \sum_i \varepsilon_{i\ Y_i}) \cdot \dot{Y}^{\varepsilon} + \sum_m \varepsilon_{X_{K,m}} \cdot \dot{X}_{K,m} + \sum_n \varepsilon_{Z_n} \cdot \dot{Z}_n + \dot{g} + \dot{\eta}.\end{aligned} \qquad [6]$$

Here Y^{ε} is an output quantity index. Its growth rate is a weighted average of the growth rates of the output quantity measures. The weight for each output measure i is the share of the corresponding cost elasticity in the sum of the output-related cost elasticities. Notice that there are *two* terms in [6] (the second and the third) that address the impact of output growth on cost.

2.1.2 Productivity Indexes

A productivity index is the ratio of an output quantity index to an input quantity index.

$$Productivity = \frac{Output\ Quantities}{Input\ Quantities}. \qquad [7]$$

It is used to compare the efficiency with which firms convert inputs to outputs. Comparisons can be made between firms at a point in time or for the same firm (or group of firms) at different points in time. The indexes we developed for this study measure only productivity trends.

The growth trend in a productivity trend index is the difference between the trends in the component output and input quantity indexes.

$$trend\ Productivity = trend\ Output\ Quantities - trend\ Input\ Quantities\ . \quad [8]$$

Productivity grows when the output quantity index rises more rapidly (or falls less rapidly) than the input quantity index.

The output quantity index summarizes trends in the output measures. The input quantity index summarizes trends in the amounts of production inputs used. Since more than one input can be considered, it is possible to construct multi-factor productivity indexes. An index that measures growth in the productivity of all inputs is called a *total* factor productivity ("TFP") index. An index that measures the growth in only a subset of all inputs used is called a *partial* factor productivity ("PFP") index.

One example of a PFP index would be an index of growth in the productivity of O&M inputs (PFP_{OM}). Indexes of this kind are useful in making output growth projections. To understand why, suppose that the growth rate of PFP_{OM} is the difference between the growth rates of an elasticity-weighted output quantity index as defined above and an input quantity index (X_{OM}).

$$P\dot{F}P_{OM} \ = \ \dot{Y}^{\varepsilon} - \dot{X}_{OM}\ . \quad [9]$$

The growth rate of the input quantity index can be shown to be the difference between the growth rates of cost and an input price index (W_{OM}).

$$\dot{X}_{OM} = \ \dot{C}_{OM} - \dot{W}_{OM}\ . \quad [10]$$

In other words, it is the growth in opex that is not due to the growth in the prices of O&M inputs. The input price index is in this case constructed from actual rather than optimal cost shares.

Equations [9] and [10] imply that

$$P\dot{F}P_{OM} = \dot{Y}^{\varepsilon} - (\dot{C}_{OM} - \dot{W}_{OM}) \quad [11]$$

Assuming that $\dot{W}_{OM} = \dot{W}^{*}_{OM}$, Equations [6] and [11] imply that

$$P\dot{F}P_{OM} = (1 - \sum_{i} \varepsilon_{i\ Y_i}) \cdot \dot{Y}^{\varepsilon} - \sum_{m} \varepsilon_{X_{K,m}} \cdot \dot{X}_{K,m} - \sum_{n} \varepsilon_{Z_n} \cdot \dot{Z}_n - \dot{g} - \dot{\eta} \quad [12]$$

so that

$$\dot{C}_{OM} = \dot{W}_{OM} - P\dot{F}P_{OM} + \dot{Y}^{\varepsilon}. \quad [13]$$

The result in equation [13] is highly useful in the projection of opex growth. We see that the growth rate of opex equals the growth rate of an O&M input price index less the growth rate in an O&M input productivity index plus the growth rate of the elasticity-weighted output quantity index.[8] Notice that the theory suggests that the growth in cost may depend on the growth in several output quantity variables.

Equation [12] is also of interest since it illuminates the forces that drive growth in a productivity index. The results presented here pertain to the productivity of O&M inputs. However, analogous results exist for TFP.

Inspecting [12], it can be seen that the growth rate of the productivity index has been decomposed into five terms. The first is the **scale economy effect**. Scale economies are realized if technology permits returns to scale and the output quantity grows. When incremental returns to scale can be realized, cost grows more slowly than output so that *unit* cost declines with rising output. Incremental returns to scale are available if the sum of the cost elasticities with respect to the output variables is less than one.

This result is important in the context of Victorian regulation. The ESC in its Gas Accord decision expressed uncertainty regarding the need to reduce the output growth adjustment for the realization of scale economies. In reality, equations [12] and [13] show that any cost-containing benefit that results from the realization of scale economies is captured in the *productivity* index. Another useful way to express this concept is to say that when we decompose cost growth into input price, productivity, and output index growth, the output index does not capture the full effect of output growth on cost. It is inappropriate, then, to impose a scale economy "discount" on the cost impact of output growth when a productivity index of the kind described is also used in cost growth projections. If such a discount is made, the measure of productivity growth should be modified to exclude scale economies.

The second term measures the effect on opex of changes in the capital quantities. We may call this the **capital quantity effect**. To illustrate its character, consider the situation in which depreciation of assets is not offset by new investment. The $X_{K,m}$

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[8] The PFP index is constructed using the same elasticity weighted output quantity index.

variables would then decline in value. This could well raise O&M expenses and reduce the productivity of O&M inputs.

The third term measures the effect on productivity growth of changes in the values of the Z variables. We will call this the **Z variable effect**. If the cost impact of a given Z variable, *n*, is positive (negative), an increase in the value of the variable will decelerate (accelerate) productivity growth. To provide one example, an increase in the frequency of severe storms in a DB's service territory might accelerate cost growth and slow productivity growth.

The fourth term measures the effect on productivity growth of the shift in the cost function. It represents the **technological change effect**. A downward shift in the cost function due to technological change will accelerate productivity growth.

The fifth term measures the effect on productivity growth of a change in the inefficiency factor. We will call this the **inefficiency effect**. An increase (decrease) in inefficiency will reduce (lower) cost and accelerate (decelerate) productivity growth.

A change in performance incentives can change the propensity of a firm to change its level of inefficiency. For example, a strengthening of incentives should encourage a firm to reduce its inefficiency and thereby move its cost closer to the frontier made possible by current technology. It is important to note, however, that the ability of firms to accelerate their productivity growth in this manner is limited by the extent of their inefficiency.

2.2 Implications for Growth Projections

Let us now consider how these results can be used to project O&M expenses. Equation [13] suggest that a projection can be made based on three indexing tasks. Task one is to forecast the growth rate in an index of the prices of O&M inputs. We will call this the input price adjustment. The task requires forecasts of growth in the prices of important input groups. The cost shares could be those for SPI Networks or for a broader aggregation of firms.

Alternative forms are available for the input price indexes. Here are two that have ample precedent:

Tornqvist

$$\ln\left(\frac{Input\ Prices_t}{Input\ Prices_{t-1}} \right) = \sum_j \ \frac{1}{2} \cdot \left(SC_{j,t} + SC_{j,t-1} \right) \cdot \ln\left(\frac{W_{j,t}}{W_{j,t-1}} \right) \quad [14a]$$

Laspeyres

$$\frac{Input\ Prices_t}{Input\ Prices_{t-1}} = \sum_j \ SC_{j,t-1} \cdot \left(\frac{W_{j,t}}{W_{j,t-1}} \right). \quad [14b]$$

Here in each year *t*,

$Input\ Prices_t$ = Input price index

$W_{j,t}$ = Price subindex for input category *j*

$SC_{j,t}$ = Share of input category *j* in applicable total cost.

The term ln indicates a natural logarithm.

Task two is to subtract the likely growth trend in the productivity index for O&M inputs. We will call this the productivity adjustment. In North American regulation, where TFP research is widespread, it has been common to use for this purpose the recent *historical* growth trend in the productivity index of the corresponding utility industry.

Such an index can in principle be calculated from data from DBs in Victoria or other jurisdictions. The use of Victorian data for this purpose has the special problem that they are only available for the immediate post-privatization period. This is a period during which O&M input productivity growth is likely to have been especially rapid as distributors responded to stronger performance incentives than existed before privatization. A similar problem exists with power distribution data from other jurisdictions including, most notably, Great Britain.

This problem can in principle be mitigated by measuring Victorian productivity trends using indexes of Malmquist form. A Malmquist index decomposes productivity growth into the shift in the productivity frontier and movement towards (or away from) the frontier. The shift in the productivity frontier is presumably more relevant in the establishment of DB opex targets.

The United States is an attractive alternative source of data for research on the productivity growth of power distributors. Operating data of good quality are readily available in the States for more than seventy investor-owned distributors for a period of more than ten years. None of these companies have recently experienced privatization and many have not experienced restructuring or price control regulation. There is therefore less concern than in Australia or Great Britain that productivity results reflect a pronounced and unsustainable movement towards the efficiency frontier.

Task three is to add the expected growth rate of the output quantity index. We will call this the output growth adjustment. The preparation of such a forecast requires forecasts of the relevant output quantities and estimates of the corresponding cost elasticities. The output growth forecast can in principle be that for the subject utility or for the industry as a whole. Here are two sensible formulas for the output quantity index:

$$\ln\left(\frac{Output\ Quantities_t}{Output\ Quantities_{t-1}} \right) = \sum_i \cdot SE_i \cdot \ln\left(\frac{Y_{i,t}}{Y_{i,t-1}} \right) \qquad [15a]$$

$$\frac{Output\ Quantities_t}{Output\ Quantities_{t-1}} = \sum_i \cdot SE_i \cdot \left(\frac{Y_{i,t}}{Y_{i,t-1}} \right). \qquad [15b]$$

Here

SE_i = Share of output category *i* in the sum of the estimated output-related cost elasticities

and in each year *t*,

$Output\ Quantities_t$ = Output quantity index

$Y_{i,t}$ = Quantity subindex for input category *i*.

The calculation of both the productivity trend and the output growth allowance requires estimates of the output-related cost elasticities. This is best accomplished using econometric methods. In econometric cost research, a cost function is first specified. Economic theory can guide cost model development. As discussed above, the opex incurred by an enterprise is a function of the amount of work it performs, the prices it pays for production inputs, and the capital inputs employed. Theory also provides some guidance regarding the nature of the relationship between these business conditions and cost. For example, cost is apt to be higher the higher are input prices and the greater is the workload.

A branch of statistics called econometrics has developed procedures for estimating parameters of economic models. Cost model parameters can be estimated econometrically using historical data on the costs incurred by utilities and on the business conditions they faced. With these estimates in hand, it is straightforward to calculate the corresponding cost elasticities.

Numerous statistical methods have been established in the econometrics literature for estimating parameters of economic models. Tests are available for the hypothesis that the parameter for a business condition variable equals zero. Variables can be excluded from the model when such hypotheses cannot be rejected.

2.2.1 The Sustainability Issue

In trying to project future growth in the productivity of O&M inputs using indexes there arises a sustainability issue. In short, growth in the *total* factor productivity of power distribution has been driven for many years by rapid growth in the productivity of O&M inputs. It is not clear that this partial factor productivity growth can be sustained. Adjustments are possible to the methodology detailed above to account for this consideration. For instance, we can take as our prediction of future growth in PFP_{OM} the average of the historical trends in PFP_{OM} and in the corresponding TFP index.

3. RELEVANT PRECEDENTS

The use of productivity indexes in utility regulation began in North America and is most widespread there. The Staggers Rail Act of 1980 prescribed the use of a Rail Cost Adjustment Factor to establish a zone of freedom for rates of non-competitive rail services. Beginning in 1989, this factor was determined using both an industry-specific input price index and an industry productivity index. Productivity indexes have since become widely used in North American telecommunications regulation and are also used in numerous price control plans for energy utilities.

It is useful to examine the accumulated precedents from North American energy utility regulation for evidence that regulators there have accepted the index logic that we present in Section 2 above. Indexes approved for the escalation of the *revenue requirement* or components thereof rather than *prices* are especially relevant since they require a decision regarding an output growth allowance in addition to decisions regarding inflation and productivity allowances.

Our review identified four approved North American plans in which revenue requirements or components thereof were escalated by indexes with specific inflation, productivity, and output growth components. Three of these plans applied to Canadian utilities and one to a U.S. utility. All of these utilities were large gas distributors. The three Canadian plans applied only to (non-gas) opex. The U.S. plan applied to the entire base (non-gas) revenue requirement. In all four cases, the output growth allowance was, essentially, the full growth rate of the number of customers served. Details of these four revenue requirement indexes can be found in the Appendix.

The Appendix also presents details of a revenue requirement adjustment mechanism for the power distribution operations of Southern California Edison. This mechanism, which pertains to the entire base revenue requirement, has fairly standard inflation and productivity components plus an allowance for new customer growth. The allowance was USD 657 per customer for 2001 and USD 669 for 2002.

4. EMPIRICAL RESEARCH

This section presents an overview of our empirical work for SPI. The discussions here are largely non-technical. Additional and more technical details of the work are provided in the Appendix.

4.1 Data

The primary source of the cost and quantity data used in the power distribution work was the Federal Energy Regulatory Commission (FERC) Form 1. Major investor-owned electric utilities in the United States are required by law to file this form annually. Data reported on Form 1 must conform to the FERC's Uniform System of Accounts. Details of these Accounts can be found in Title 18 of the Code of Federal Regulations.

FERC Form 1 data are processed by the Energy Information Administration ("EIA") of the U.S. Department of Energy. Selected Form 1 data were for many years published by the EIA.[9] More recently, the data have been available electronically from firms like the Utility Data Institute ("UDI"). FERC Form 1 data used in this study for years since 1984 were obtained from UDI and Form 1 reports.

Data were considered for inclusion in the sample from all major U.S. investor-owned electric power distributors that filed the Form 1 in 2003 and that, together with any important predecessor companies, have reported the necessary data continuously since the mid 1960s. To be included in the study the data were required, additionally, to be plausible. Data from 75 companies met these standards and were used in our indexing work. Data for 72 companies were used in the supportive econometric work. We believe that these data are the best available for rigorous work on the productivity trends of U.S. power distributors. The included companies are listed in Table 1.[10]

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[9] This publication series, which has been suspended, had several titles over the years. A recent title is *Financial Statistics of Major U.S. Investor-Owned Electric Utilities.*

[10] The sample for the TFP trend work includes some companies that were excluded from the sample for the econometric cost benchmarking work. These companies were deemed to have satisfactory cost and output quantity data despite flaws in data for one or more of the additional business condition variables that are not used in the TFP trend work.

Table 1

SAMPLED POWER DISTRIBUTORS FOR THE EMPIRICAL RESEARCH

Alabama Power
AmerenUE
Appalachian Power
Arizona Public Service
Atlantic City Electric
Avista
Baltimore Gas & Electric
Bangor Hydro-Electric
Black Hills
Boston Edison
Carolina Power & Light
Central Hudson Gas & Electric
Central Maine Power
Central Vermont Public Service
Cincinnati Gas & Electric
Cleco
Cleveland Electric Illuminating
Columbus Southern Power
Connecticut Light & Power
Duke Energy
Edison Sault Electric
El Paso Electric
Empire District Electric
Entergy New Orleans
Florida Power & Light
Florida Power
Green Mountain Power
Hawaiian Electric
Idaho Power
Kansas City Power & Light
Kansas Gas and Electric
Kentucky Power
Kentucky Utilities
Kingsport Power
Louisville Gas and Electric
Madison Gas and Electric
Maine Public Service
Mississippi Power
Mount Carmel Public Utility
Nevada Power
Northern Indiana Public Service
Northern States Power
Ohio Edison
Ohio Power
Oklahoma Gas and Electric
Orange and Rockland Utilities
Otter Tail Power
Pacific Gas and Electric
PacifiCorp
Potomac Edison
Potomac Electric Power
PSI Energy
Public Service of Colorado
Public Service of New Hampshire
Public Service of Oklahoma
Public Service Electric and Gas
Rochester Gas and Electric
San Diego Gas & Electric
South Carolina Electric & Gas
Southern California Edison
Southern Indiana Gas and Electric
Southwestern Electric Power
Southwestern Public Service
Tampa Electric
Texas-New Mexico Power
Toledo Edison
Tucson Electric Power
Union Light Heat & Power
United Illuminating
Virginia Electric and Power
West Penn Power
Western Massachusetts Electric
Wisconsin Electric Power
Wisconsin Power and Light
Wisconsin Public Service

Number of Companies: 75 Indexing Work
72 Econometric Work

* Companies in italics were included in the indexing sample but not the econometric sample

Other sources of data were also accessed in the research. These were used primarily to measure input prices. The supplemental data sources were Whitman, Requardt & Associates; R.S. Means and Associates; the Bureau of Economic Analysis ("BEA") of the U.S. Department of Commerce; and the Bureau of Labour Statistics ("BLS") of the U.S. Department of Labour.

4.2 Productivity Research

4.2.1 Scope

We calculated indexes of the TFP and (opex) PFP trends of the sampled utilities as power distributors.[11] The applicable services included local power distribution, sales, and customer account and information services.[12] Given the limited role of Victorian DBs in the latter three areas we reduced the corresponding costs by 80%. In the TFP work, the relevant costs considered comprised the cost of capital in addition to opex. In the calculation of both indexes, cost was defined to include shares of a utility's administrative and general ("A&G") expenses and of its costs of general plant ownership.

The decomposition of capital cost trends into price and quantity trends is essential if we are to measure the TFP trend. The study used a service price approach to capital cost measurement. Under this approach, the cost of capital is the product of a capital quantity index and an index of the price of capital services. This method has a solid basis in economics and is well established in the scholarly literature.

4.2.2 Productivity Indexes

The growth rate in each industry productivity index is the difference between the growth rates in industry output and input quantity indexes. The growth rate in each output quantity index is a weighted average of the growth rates of the relevant output quantities. Three output quantities were found to be relevant in the measurement of TFP: residential

[11] Most of the sampled utilities also own power transmission networks, and some are involved extensively in generation. Their filings must by law conform to a Uniform System of Accounts that includes detailed guidelines for the allocation of costs between these categories.

[12] The term "distribution" in the Uniform System of Accounts pertains chiefly to voltage reduction and local power delivery services.

deliveries, other retail deliveries, and the number of customers served. The corresponding weights were the shares of these three variables in the sum of the estimated output-related cost elasticities.

The elasticity estimates for the TFP index were drawn from an econometric model of total power distribution cost developed by the authors and reported in 2002 price control testimony for San Diego Gas and Electric, a U.S. power distributor. The resulting weights used are: .117 for residential deliveries, .206 for other deliveries, and .676 for the number of customers. It follows that while the number of customers was the dominant output-related cost driver during the sample period, delivery volumes also mattered.

Our output quantity specification for PFP was based on an original econometric analysis of opex that was undertaken as a part of this study. We found that only the number of customers was relevant in measuring the productivity trend of O&M inputs. Hence, there proved to be no issue of elasticity weights.

The growth rate in each input quantity index is a weighted average of the growth rates in quantity subindexes. In the case of TFP there are quantity subindexes for capital, labour, and other O&M inputs. The weights are based on the shares of these input classes in the industry's total power distribution cost. In the case of O&M PFP there are quantity subindexes for labour and other O&M inputs. The weights are based on the shares of these input classes in the industry's power distribution opex.

4.2.3 Sample Period

The start and end dates for the calculation of a productivity trend are generally less important when the number of customers has a large weight in the output quantity index than when the index is quite sensitive to the volumes delivered or other volatile variables. A key consideration is that the sample period be long enough to reflect the long run trend. We generally desire a sample period of at least 10 years to fulfill this goal. The year 2003 is the most recent for which the requisite data are available. The sample period was thus 1993-2003 for both indexes. The sample period for the supportive econometric work used to develop the PFP output quantity index was 1991-2003.

4.2.4 Results

Tables 2-4 report the 1993-2003 growth trends for productivity, output quantities, and input quantities of the sampled distributors. Inspecting the results, it can be seen that the TFP of the U.S. power distribution industry exhibited 0.69% average annual growth. Output quantity growth averaging 1.72% annually outpaced input quantity growth averaging 1.03% annually.

Inspecting the PFP results for O&M inputs it can be seen that the trend in industry PFP was 0.82% annual growth, modestly above the trend for TFP. Customer growth averaging 1.60% annually outpaced input quantity growth averaging 0.78% annually. The output quantity trend differs from that for TFP due to different output index weights. Our econometric opex research revealed that the typical U.S. distributor in the sample realized considerable economies of scale. The realization of scale economies was thus an important source of productivity growth during the sample period.

4.3 Input Price Adjustment

We predict the input price growth of SPI using an input price index as shown in Table 5. The annual growth of the index is a weighted average of the growth in the prices of two categories of O&M inputs: technical labour and the other miscellaneous inputs. The shares of these input categories in the opex of SPI are the weights.

The requisite data for the construction of the index were provided by SPI. The recent forecast for growth in the price of technical labour is discussed in SPI's submission to the Commission. Prices for other labour and other O&M inputs are assumed to rise by the growth rate in the CPI. SPI has provided us with an estimate of 2.56% of the average annual CPI growth. Inspecting Table 5, it can be seen that input prices are forecasted to grow by about 3.82% annually on average over the 2006-2010 period.

Table 2

Productivity Trends

Year	**TFP Index**	Output Quantity Index	Input Index	**PFP Index**	Output Quantity Index	Input Index
1992	1.000	1.000	1.000	1.000	1.000	1.000
1993	0.993	1.014	1.021	0.971	1.009	1.039
1994	1.004	1.032	1.028	1.003	1.024	1.021
1995	1.020	1.050	1.029	1.045	1.038	0.993
1996	1.018	1.063	1.044	1.024	1.047	1.023
1997	1.035	1.078	1.042	1.073	1.059	0.987
1998	1.023	1.090	1.065	1.017	1.063	1.045
1999	1.037	1.118	1.078	1.026	1.092	1.064
2000	1.005	1.098	1.092	0.979	1.061	1.084
2001	1.009	1.106	1.096	1.027	1.083	1.054
2002	1.063	1.176	1.107	1.091	1.156	1.060
2003	1.064	1.204	1.132	1.054	1.185	1.124
Average Annual Growth Rates						
1993-2003	**0.69%**	**1.72%**	**1.03%**	**0.82%**	**1.60%**	**0.78%**

Table 3

Output Quantity Trends

	Quantity Measures			TFP Weights			PFP Weights	Summary Indexes	
Year	Customers	Residential Volume	Other Retail Volume	Customers	Res. Volume	Other Retail Volume	Customers	TFP	PFP (O&M)
1992	1.000	1.000	1.000	67.6%	11.7%	20.6%	100.0%	1.000	1.000
1993	1.009	1.047	1.011	67.6%	11.7%	20.6%	100.0%	1.014	1.009
1994	1.024	1.067	1.040	67.6%	11.7%	20.6%	100.0%	1.032	1.024
1995	1.038	1.098	1.062	67.6%	11.7%	20.6%	100.0%	1.050	1.038
1996	1.047	1.129	1.080	67.6%	11.7%	20.6%	100.0%	1.063	1.047
1997	1.059	1.129	1.111	67.6%	11.7%	20.6%	100.0%	1.078	1.059
1998	1.063	1.172	1.135	67.6%	11.7%	20.6%	100.0%	1.090	1.063
1999	1.092	1.204	1.158	67.6%	11.7%	20.6%	100.0%	1.118	1.092
2000	1.061	1.217	1.158	67.6%	11.7%	20.6%	100.0%	1.098	1.061
2001	1.083	1.132	1.172	67.6%	11.7%	20.6%	100.0%	1.106	1.083
2002	1.156	1.303	1.177	67.6%	11.7%	20.6%	100.0%	1.176	1.156
2003	1.184	1.344	1.196	67.6%	11.7%	20.6%	100.0%	1.204	1.185
Average Annual Growth Rates									
1993-2003	**1.60%**	**2.50%**	**1.68%**					**1.72%**	**1.60%**

Table 4

Input Quantity Trends

Year	Input Quantity Measures				Summary Indexes	
	Labor Subindex	Non-Labor O&M Subindex	Capital Subindex (Distribution)	Capital Subindex (General)	TFP	PFP (O&M)
1992	1.000	1.000	1.000	1.000	1.000	1.000
1993	1.015	1.068	1.014	1.060	1.021	1.039
1994	0.941	1.118	1.026	1.173	1.028	1.021
1995	0.913	1.091	1.037	1.170	1.029	0.993
1996	0.907	1.164	1.048	1.181	1.044	1.023
1997	0.847	1.160	1.056	1.128	1.042	0.987
1998	0.850	1.285	1.069	1.178	1.065	1.045
1999	0.878	1.293	1.078	1.249	1.078	1.064
2000	0.871	1.345	1.091	1.242	1.092	1.084
2001	0.833	1.325	1.105	1.269	1.096	1.054
2002	0.793	1.389	1.119	1.226	1.107	1.060
2003	0.823	1.498	1.131	1.241	1.132	1.124
Average Annual Growth Rates						
1993-2003	**-2.10%**	**3.38%**	**1.09%**	**1.58%**	**1.03%**	**0.78%**

Table 5

Input Price Allowance

	Projected Input Price Growth		Cost Shares		Input Price Allowance
Year	Technical Labour	Other	Technical Labour	Other	
2005	7.06%	2.56%	28%	72%	3.82%
2006	7.06%	2.56%	28%	72%	3.82%
2007	7.06%	2.56%	28%	72%	3.82%
2008	7.06%	2.56%	28%	72%	3.82%
2009	7.06%	2.56%	28%	72%	3.82%
2010	7.06%	2.56%	28%	72%	3.82%

4.4 Output Quantity Adjustment

Our discussion in Section 2 revealed that the kind of output quantity index used to measure PFP growth is also useful in calculating an output growth allowance. This index is simply the number of customers served in the present case. In Table 6, we present results of a forecast of the output growth allowance that would be appropriate for SPI. The forecast makes use of projections of growth in the number of customers served by SPI. These projections were provided by the company. The output growth allowances average 1.99% over the 2006-2010 period.

4.5 Total Opex Growth Projections

Table 7 presents our projection of SPI opex over the 2006-2010 period using the index methodology detailed in Section 2. In this calculation, we simply add the input price, productivity, and output growth allowances. We obtain a total opex rate of growth that averages 4.99% annually over the period. In other words, opex should grow in *nominal* terms by 4.99% annually. Assuming that the escalation mechanism for target opex uses the CPI as an inflation measure, the mechanism should permit opex to grow 4.99 – 2.56 = 2.43% more rapidly each year than the CPI.

Table 6

Output Growth Allowance

Year	Number of Customers		Output Growth Allowance
	Total	Growth Rate	
2004	550,126		
2005	558,378	1.49%	1.49%
2006	570,778	2.20%	2.20%
2007	581,741	1.90%	1.90%
2008	593,149	1.94%	1.94%
2009	604,466	1.89%	1.89%
2010	616,936	2.04%	2.04%
Averages			
2004-2006		1.84%	1.84%
2004-2010		1.91%	1.91%
2006-2010		**1.99%**	**1.99%**

Table 7

Opex Projections

	Opex Adjustments			Total Rate of Change
	Input Prices	Productivity	Output Growth	
Year	[A]	[B]	[C]	[A] - [B] + [C]
2005	3.82%	0.82%	1.49%	4.5%
2006	3.82%	0.82%	2.20%	5.2%
2007	3.82%	0.82%	1.90%	4.9%
2008	3.82%	0.82%	1.94%	4.9%
2009	3.82%	0.82%	1.89%	4.9%
2010	3.82%	0.82%	2.04%	5.0%
Averages				
2004-2006	3.82%	0.82%	1.84%	4.84%
2004-2010	3.82%	0.82%	1.91%	4.91%
2006-2010	**3.82%**	**0.82%**	**1.99%**	**4.99%**

APPENDIX

A.1 Input Quantity Indexes

The growth rates of the input quantity indexes were defined by formulas. These formulas involved subindexes measuring growth in the amounts of various inputs used. Major decisions in the design of such indexes include their form and the choice of input categories and quantity subindexes.

A.1.1 Index Form

Each industry input quantity index was of Törnqvist form.[13] The annual growth rate of the index was determined by the formula:

$$\ln\left(\frac{Input\ Quantities_t}{Input\ Quantities_{t-1}} \right) = \sum_j \frac{1}{2} \cdot \left(SC_{j,t} + SC_{j,t-1} \right) \cdot \ln\left(\frac{X_{j,t}}{X_{j,t-1}} \right). \qquad [16]$$

Here in each year *t*,

$Input\ Quantities_t$ = Input quantity index

$X_{j,t}$ = Quantity subindex for input category *j*

$SC_{j,t}$ = Share of input category *j* in applicable total cost.

It can be seen that the growth rate of such an index is a weighted average of the growth rates of the input quantity subindexes. Each growth rate is calculated as the logarithm of the ratio of the quantities in successive years. Data on the average shares of each input in the applicable cost of sampled distributors during these years are the weights.

A.1.2 Input Quantity Subindexes

The growth rate of each industry input quantity subindex $X_{j,t}$ equals a weighted average of the corresponding growth rates for the individual sampled companies. The shares of each company in the total cost of the sampled firms are used to calculate the weights.

For each sampled company in both studies, the quantity subindex for labour was the ratio of the regional salary and wage expenses to a labour price index constructed using the BLS Employment Cost Index for the electric, gas, and sanitary sector. The quantity subindex for other O&M inputs was the ratio of the expenses for other O&M inputs to the gross domestic product price index (GDPPI). The quantity subindexes for capital are discussed in Section A.3 below.

A.1.3 Detailed Results

Detailed input quantity results can be found in Table 4. It can be seen that the quantities of distribution and general plant had 1.09% and 1.58% average annual growth rates, respectively. The quantity of labour services fell by 2.10% annually, while the quantity of other O&M inputs rose by 3.38% annually. These results probably reflect some substitution of capital and other O&M inputs for labour during the sample period. They may also reflect the movement of some labour services to affiliates of some reporting utilities. The markedly different results for labor and other O&M inputs mean that the TFP trend of an industry can differ markedly from the multifactor productivity trend of labour and capital in the industry.

A.2 Output Quantity Indexes

The growth rates of the output quantity indexes were defined by formulas. These formulas accommodated subindexes measuring growth in the amounts of various inputs used. Major decisions in the design of the indexes include their form and the choice of input categories and quantity subindexes.

The output quantity indexes had the following general form:

$$\ln\left(\frac{Output\ Quantities_t}{Output\ Quantities_{t-1}} \right) = \sum_i \cdot SE_i \cdot \ln\left(\frac{Y_{i,t}}{Y_{i,t-1}} \right). \qquad [15a]$$

Here

SE_i = Share of output category i in the sum of the estimated output-related cost elasticities

[13] For seminal discussions of this index form see Törnqvist (1936) and Theil (1965).

and in each year *t*,

$Output\ Quantities_t$ = Output quantity index

$Y_{i,t}$ = Quantity subindex for input category *i.*

It can be seen that the growth rate of the index is a weighted average of the growth rates of the individual output quantity variables. The growth rate of each output quantity variable is calculated as the logarithm of the ratio of the quantities in successive years. The shares of each input in the sum of the econometric estimates of the corresponding cost elasticities are the weights. The industry rate of change in each output quantity measure was calculated as a weighted average of the corresponding rates of change for the individual companies. The weights were based on the share of each company in the aggregate cost.

As noted in Section 4, econometric research identified only one output quantity variable for O&M inputs: the number of customers served. In this case, the formula above reduces to the growth in the customers served by the aggregate.

A.3 Capital Cost

A service price approach was chosen to measure capital cost. This approach has a solid basis in economic theory and is widely used in scholarly empirical work.[14] In the application of the general method used in this study, the cost of a given class of utility plant *j* in a given year *t* ($CK_{j,t}$) is the product of a capital service price index ($WKS_{j,t}$) and an index of the capital quantity at the end of the prior year ($XK_{j,t-1}$).

$$CK_{j,t} = WKS_{j,t} \cdot XK_{j,t-1}. \qquad [18]$$

Each capital quantity index is constructed using inflation-adjusted data on the value of utility plant. Each service price index measures the trend in the hypothetical price of capital services from the assets in a competitive rental market.

There are two categories of utility plant: power distribution plant and general plant. The power distribution plant data from FERC Form 1 included the value of plant for local delivery and metering. In constructing capital quantity indexes, we took 1964 as the benchmark or staring year. The values for these indexes in the benchmark year are based on the net value of plant as reported in the FERC Form 1. We estimated the benchmark year (inflation adjusted) value of net plant by dividing this book value by an average of the values of an index of utility construction cost for a period ending in the benchmark year. The construction cost index (WKA_t) was the applicable regional Handy-Whitman index of utility construction costs for the relevant asset category.[15]

The following formula was used to compute subsequent values of the capital quantity index:

$$XK_{j,t} = (1-d) \cdot XK_{j,t-1} + \frac{VI_{j,t}}{WKA_{j,t}}. \qquad [19]$$

Here, the parameter d is the economic depreciation rate and $VI_{j,t}$ is the value of gross additions to utility plant.

The economic depreciation rate was calculated as a weighted average of the depreciation rates for the structures and equipment used in the applicable industry. The depreciation rate for each structure and equipment category was derived from data reported by the BEA.

The full formula for the capital service price indexes used in the TFP trend research was

$$WKS_{j,t} = [CK_{j,t}^{Taxes} / XK_{j,t-1}] + d \cdot WKA_{j,t} + WKA_{j,t-1}\left[r_t - \frac{(WKA_{j,t} - WKA_{j,t-1})}{WKA_{j,t-1}}\right]. \qquad [20]$$

The first term in the expression corresponds to taxes and franchise fees. The second term corresponds to the cost of depreciation. The third term corresponds to the real rate of return on capital. This term was smoothed to reduce capital cost volatility.

In both formulas, r_t is the opportunity cost of plant ownership per dollar of plant value. As a proxy for this we calculated the user cost of capital for the U.S. economy

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[14] See Hall and Jorgensen (1967) for a seminal discussion of the service price method of capital cost measurement.

[15] These data are reported in the *Handy-Whitman Index of Public Utility Construction Costs*, a publication of Whitman, Requardt and Associates.

using data in the National Income and Product Accounts (NIPA).[16] This variable reflects returns on equity as well as bond yields. The NIPA accounts are published by the BEA in its *Survey of Current Business* series.

A.4 TFP Growth Rates and Trends

The annual growth rate in the industry TFP index is given by the formula

$$\ln\left(\frac{TFP_t}{TFP_{t-1}}\right) = \ln\left(\frac{Output\ Quantities_t}{Output\ Quantities_{t-1}}\right) - \ln\left(\frac{Input\ Quantities_t}{Input\ Quantities_{t-1}}\right). \qquad [21]$$

Since the index formulas involve annual growth rates, some method is needed to calculate long run trends from the annual growth rates. The long run trend in each TFP index was calculated as its average annual growth rate over the sample period.

A.5 Econometric Research

A.5.1 Business Condition Variables

Output Quantities

As noted above, economic theory suggests that the quantities of work performed by utilities should be included in our cost model as business condition variables. There is one output quantity variable in our opex model: the number of retail customers served. We expect cost to be higher the higher is the value of this variable.

Input Prices

Cost theory also suggests that the prices paid for production inputs are relevant business condition variables. In this model, we have specified input price variables for labour and other O&M inputs. We expect cost to be higher the higher are the values of both of these price variables.

The labour price variable used in this study was constructed by PEG using data from the BLS. National Compensation Survey ("NCS") data for 1998 were used to

[16] These data are reported in the *Handy-Whitman Index of Public Utility Construction Costs*, a

construct average wage rates that correspond to each distributor's service territory. The wage levels were calculated as a weighted average of the NCS pay level for each job category using weights that correspond to the electric, gas, and sanitary (EGS) sector for the U.S. as a whole. Values for other years were calculated by adjusting the 1998 level for changes in regional indexes of employment cost trends for the EGS sector. These indexes were also constructed from BLS data.

Prices for other O&M inputs are assumed to be the same in a given year for all companies. They are escalated by the gross domestic product price index (GDPPI). The parameter of this variable is estimated indirectly.

Other Business Conditions

Three additional business condition variables are included in the cost model. One is the total length of the distribution system. This is added as a measure of system extensiveness. It captures the special cost challenges faced by distributors serving rural areas. It is sometimes treated as an output variable in distribution cost studies but does not typically involve special charges to customers, as is the case with delivery volumes and the number of customers served. We have data for this variable for only one year, 2001.

Another business condition added to this model is the average precipitation in the service territory. We expect this variable to have a higher value the greater is the extent of forestation in the service territory. Forestation raises the cost of overhead lines. We therefore expect the value of this variable's parameter to be positive.

A third business condition variable added to the model is the number of customers that the utility provides with gas distribution services. This variable is intended to capture the extent to which the company has diversified into gas distribution. Such diversification can, in the long run, lower cost due to the realization of scope economies. The extent of diversification is greater the greater is the value of the variable. We therefore expect the value of this variable's parameter to be negative.

The model also contains a trend variable. This permits cost to shift over time for reasons other than changes in the specified business conditions. A trend variable captures

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publication of Whitman, Requardt and Associates.

the net effect on cost of diverse conditions, including technological change. We expect the value of this variable's parameter to be negative.

Other variables were considered in our econometric opex research for SPI but were not included in the final model due to unsatisfactory statistical results. These included a capital quantity variable, various volume variables, and a measure of substation (voltage transformation) effort.

A.5.2 Form of the Cost Model

The functional form employed in this study was the translog.[17] This very flexible form is the most frequently used in econometric cost research, and by some accounts is the most reliable of several available alternatives.[18] The general form of the translog econometric cost model is:

$$\begin{aligned}\ln C = \alpha_o + \sum_i \alpha_i \ln Y_i + \sum_j \alpha_j \ln W_j \\ + \frac{1}{2}\left[\sum_i \sum_k \gamma_{hk} \ln Y_i \ln Y_k + \sum_j \sum_n \gamma_{jn} \ln W_j \ln W_n\right] \\ + \sum_i \sum_j \gamma_{hj} \ln Y_i \ln W_j + \sum_\ell \alpha_\ell \ln Z_\ell + \alpha_t T + \mu.\end{aligned} \qquad [22]$$

Here, Y_i can denote one of several variables that quantify output and W_j can denote one of several input prices. The *Z*'s denote the additional business conditions, *T* is a trend variable, and μ denotes the error term. Note that to limit model complexity we do not translog the Z variables or T.

Estimation of the parameters in Equation [22] is now possible but this approach does not utilize all information available in helping to explain the factors that determine cost. Better parameter estimates can be obtained by augmenting the cost equation with some of the cost share equations implied by Shepard's Lemma. The general form of a cost share equation for a representative input price category, *j*, can be written as:

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[17] The transcendental logarithmic (or translog) cost function can be derived mathematically as a second order Taylor series expansion of the logarithmic value of an arbitrary cost function around a vector of input prices and output quantities.

[18] See Guilkey (1983), et. al.

$$S_j = \alpha_j + \sum_i \gamma_{hj} \ln Y_i + \sum_n \gamma_{jn} \ln W_n \quad [23]$$

Note that the parameters in this equation also appear in the cost model. Since the share equations for each input price are derived from the first derivative of the translog cost function with respect to that input price, this should come to no surprise. Because of these cross-equation restrictions, the total number of coefficients in this system of equations will be no larger than the number of coefficients required to be estimated in the cost equation itself.

A.5.3 Estimation Procedure

With regard to the estimation procedure, we chose to employ a seemingly unrelated regression (SUR) procedure first proposed by Zellner (1962).[19] It is well known that if there exists contemporaneous correlation between the error terms in a system of regression equations, more efficient estimates of their parameters can be obtained using a Feasible Generalized Least Squares (FGLS) approach. To achieve an even better estimator, we iterated this procedure to convergence.[20] Since we estimated these unknown disturbance matrices consistently, the estimators we eventually computed are equivalent to Maximum Likelihood Estimation (MLE).[21] Our estimates thus possess all the highly desirable properties of MLE's.

Before proceeding with estimation, there is one complication that needs to be addressed. Since the cost share equations by definition must sum to one at every observation, one cost share equation is redundant and must be dropped.[22] This does not pose a problem since another property of the MLE procedure is that it is invariant to any such reparameterization. Hence, the choice of which equation to drop will not affect the resulting estimates.

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[19] See Zellner, A. (1962)

[20] That is, we iterate the procedure until the determinant of the differences between any two consecutive estimated disturbance matrices are approximately zero.

[21] See Dhrymes (1971), Oberhofer and Kmenta (1974), Magnus (1978).

[22] This equation can be estimated indirectly if desired from the estimates of the parameters remaining in the model.

A.5.4 Econometric Results

Estimation Results

Estimation results for the power distribution opex model are reported in Tables 8 and 8a. The parameter values for the three additional business conditions and for the first order (non-squared) terms of the translogged variables are elasticities of the cost of the sample mean firm with respect to the basic variable. The first order terms are the terms that do not involve squared values of business condition variables or interactions between different variables. The table shades the results for these terms for reader convenience.

The table also reports the values of the asymptotic *t* ratios that correspond to each parameter estimate. These were also generated by the estimation program and were used to assess the range of possible values for parameters that are consistent with the data. A parameter estimate is deemed statistically significant if the hypothesis that the true parameter value equals zero is rejected. This statistical test requires the selection of a critical value for the asymptotic *t* ratio. In this study, we employed a critical value that is appropriate for a 90% confidence level given a large sample.

The *t* ratios were used in model specification. The output quantities and input prices (which were translogged in model specification) were required to have first order terms with statistically significant parameters. The other basic variables (which were not translogged) were also required to have statistically significant parameters.

Examining the results in Table 8, it can be seen that the cost function parameter estimates were plausible as to sign and magnitude. With regard to the first order terms of the translogged variables, cost was found to be higher the higher was the output quantity. At the sample mean, a 1% increase in the number of customers was estimated to raise cost by 0.80%. Evidently, the impact of customers on distribution cost extends well beyond the revenue cycle services. Note also that an elasticity estimate below 1 means that considerable returns to scale were available under sample mean conditions. Scale economies thus contributed to productivity growth. Turning to results for the input prices, it can be seen that a 1% increase in the labour price raised O&M expenses by 0.48%. The parameter estimates for the additional variables are all plausibly signed and highly significant.

Table 8

ECONOMETRIC COST MODEL FOR POWER DISTRIBUTION

VARIABLE KEY

WL= Labor Price
N= Number Retail Customers
P= Average Precipitation
G = Number of Gas Customers
L= Distribution Line Length

EXPLANATORY VARIABLE	ESTIMATED COEFFICIENT	T-STATISTIC	EXPLANATORY VARIABLE	ESTIMATED COEFFICIENT	T-STATISTIC
WL	0.481	137.835	Constant	13.745	885.801
WLWL	0.007	0.241			
WLN	-0.044	-15.308	Rbar-squared		0.952
N	0.803	48.115	Time Period		1991-2003
NN	0.031	4.339			
			Number of Obsevations		936
P	0.183	12.833			
G	-0.006	-4.969			
L	0.155	9.848			
Trend	-0.012	-6.270			

Table 8a

ECONOMETRIC LABOR SHARE MODEL FOR POWER DISTRIBUTION

VARIABLE KEY

WL= Labor Price
N= Number Retail Customers

EXPLANATORY VARIABLE	ESTIMATED COEFFICIENT	T-STATISTIC	EXPLANATORY VARIABLE	ESTIMATED COEFFICIENT	T-STATISTIC
WL	0.007	0.241	Constant	0.481	137.835
			Rbar-squared		0.037
N	-0.044	-15.308	Time Period		1991-2003
			Number of Obsevations		936

- Cost was lower the greater was the number of gas customers served
- Cost was higher the greater was precipitation.
- Cost was higher the greater was the length of distribution lines.
- The estimate of the trend variable parameter is –0.012. This suggests a 1.2% downward shift in cost annually for reasons other than the trends in the specific business condition variables.

The table also reports the adjusted R^2 statistic. This is a measure of the ability of the model to explain variation in the sampled costs of distributors. Its value of .955 suggests that the explanatory power of the model is high.

A.6 Summary of Regulatory Precedents

A.6.1 BC Gas I

Jurisdiction: British Columbia Utilities Commission

Order Approving Plan:

In the Matter of the BC Gas Utility Ltd. REVENUE REQUIREMENTS APPLICATION 1998-2002. In the Matter of An Application by BC Gas Utility Ltd. for Approval of a One Year Extension to the 1998-2000 Performance-Based Ratemaking Settlement to Determine Revenue Requirements for 2001. Reasons for Decision and Order, No. G-85-97, July 23, 1997.

Plan Name: Performance-Based Ratemaking

Plan Term: 1997-2001 (three years, later extended to four years)

Application: Revenue requirement for non-gas O&M expenses

Core Mechanism – O&M Expenses:

<u>Description</u>

Growth in revenue requirement for non-gas O&M expenses capped by index

<u>Formula</u>

$\text{Revenue Requirement}_{OM,t}$

$= \{\text{Revenue Requirement}_{OM,\, t-1}$

$\times [1+\text{Growth in Customers} - \text{Productivity}) \times (1+\text{Inflation})]\}$

+Cost of Defined Required Incremental Activities

Growth in Customers = Forecasted percentage growth in the average number of customers for the year over the previous year

Inflation = Forecasted rate of inflation in the CPI^{BC}

Productivity (stretched) = 2% (1998), 2% (1999), 3% (2000), 1% (2001)

A.6.2 BC Gas II

Jurisdiction: British Columbia Utilities Commission

Order Approving Plan (Name, Order Number, and Date):

An Application by Terasen Gas Inc. (formerly known as BC Gas Utility Ltd.) for Approval of a Multi-Year Performance-Based Rate Plan to Set Rates for 2004-2008. Order No. G-51-03. 29 July 2003.

Plan Name: Performance Based Rate Plan (PBR)

Plan Term: 2004-2007 (four years)

Application: Gas distribution (base rate) revenues

Application: Revenue requirement for non-gas O&M expenses

Core Mechanism – O&M Expenses:

Description

Growth in revenue requirement for non-gas O&M expenses capped by index

Formula

$\text{Revenue Requirement}_{OM,t}$

$= \{\text{Revenue Requirement}_{OM,t-1} \text{ x } [(1+\text{Growth in Customers}) \text{ x } (1+\text{Adjustment Factor})]\}$

+ Cost of Defined Required Incremental Activities.

Growth in Customers = Forecasted percentage growth in the average number of customers for the year over the previous year

Inflation = Forecasted rate of inflation in the CPIBC

Adjustment Factor = 50% of forecasted CPI growth 2004-5 (about .95%)

66% of forecasted CPI growth 2006-7 (about 1.2%)

A.6.3 Consumers' Gas[23]

Jurisdiction: Ontario Energy Board

Plan Name: Targeted PBR (Performance-Based Regulation)

Order Approving Plan:

In the Matter of an Application by The Consumers' Gas Company for approval of an incentive mechanism in relation to the Operation and Maintenance Expense component of its cost of service, effective during the 2000 through 2002 fiscal years, and an incentive mechanism in relation to Demand Side Management. E.B.R.O. 497-01. April 22, 1999.

Application: O&M expenses

Plan Term: 2000-2002

Rate Adjustment Mechanism:

<u>Description</u>

Allowed non-gas O&M expenses escalated automatically between rate cases using an index with input price, productivity, and output growth components.

<u>Formula</u>

$Opex_{Test}$ Year

$$= Opex_{Base\ Year} \times (1 + \text{Customer Growth} - \text{Productivity}) \times (1 + \text{Inflation}) \\ +/- \text{ Z Factor adjustment}$$

Inflation = growth $CPI^{Ontario}$.

Productivity (stretched) = 1.1 %.

A.6.4 Southern California Gas

Jurisdiction: California Public Utilities Commission

Order Approving Plan:

In the Matter of the Application of SOUTHERN CALIFORNIA GAS COMPANY to Adopt Performance Based Regulation ("PBR") for Base Rates to be Effective January 1, 1997. Decision No. 97-07-054, No. R87-11-012, Application No. 95-06-002. July 16, 1997.

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[23] Consumers' Gas is now called Enbridge Gas Distribution.

Plan Name: Performance Based Ratemaking (PBR)

Plan Term: 1997-2002 (five years)

Application: Gas distribution (base) revenues

Rate Adjustment Mechanism:

Description

Growth in revenue requirement per customer is capped by an index

Formula

(Revenue Requirement Per Customer_t / Revenue Requirement Per Customer_t) -1

= Inflation – X +/- Z

Inflation = growth rate in custom input price index for gas distribution industry

X = Productivity Factor

Productivity factor includes

0.5% industry TFP trend

1.0% declining rate base adjustment

Stretch factor = 0.6% (Year 1), 0.7% (Year 2), 0.8% (Year 3), 0.9% (Year 4), and 1.0% (Year 5).

Z = Z factor effecting adjustments for special events beyond company's control

A.6.5 Southern California Edison

Jurisdiction: California Public Utilities Commission

Order Approving Plan:

Order Instituting Investigation into Changing the Method, Timing, and Process for Periodically Deriving a Reasonable Revenue Requirement for the Southern California Edison Company. Decison 02-04-055, Investigation 94-040-003, 22 April 2002.

Plan Name: Performance Based Ratemaking (PBR)

Plan Term: 2001-2002

Application: Power distribution (base) revenues

Rate Adjustment Mechanism:[24]

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[24] On p. 11 of the decision the Commission comments that "No party contested either Edison's methodology or its calculation of the growth allowance."

Description

Growth in revenue requirement is escalated by a formula.

Formula

$\text{Revenue Requirement}_t = (1+(\text{growth CPI} - X)) \times \text{Annualized Revenue Requirement}_{t-1}$

$+ \ \$\,669 \times \text{Number of New Customers}_t.$

X = 0.9 (productivity) + 0.7 (stretch).

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