

Table 2

MFP Level Indexes for Gas Distribution: 1999-2003

	Output Quantity Index	Input Quantity Index	MFP Index	Percentage Difference from Sample Mean MFP *
1999	2.565	1.978	1.296	26.0%
2000	2.664	1.678	1.588	46.2%
2001	2.751	1.796	1.531	42.6%
2002	2.799	1.705	1.642	49.6%
2003	2.872	2.084	1.378	32.1%

* Percentages are calculated using logarithms.

Table 3

How Enbridge MFP Compares to Averages For Selected Peer Groups

	Gas-Only Distributors (45 companies)	> 1,000,000 Customers, Gas Only (7 companies)
	How Enbridge Compares ¹	How Enbridge Compares ¹
1999	36.50%	26.77%
2000	56.77%	47.05%
2001	53.16%	43.44%
2002	60.15%	50.43%
2003	42.61%	32.88%

¹ Percentages are calculated logarithmically

Figure 1

MFP Level Indexes For Enbridge Gas Distribution

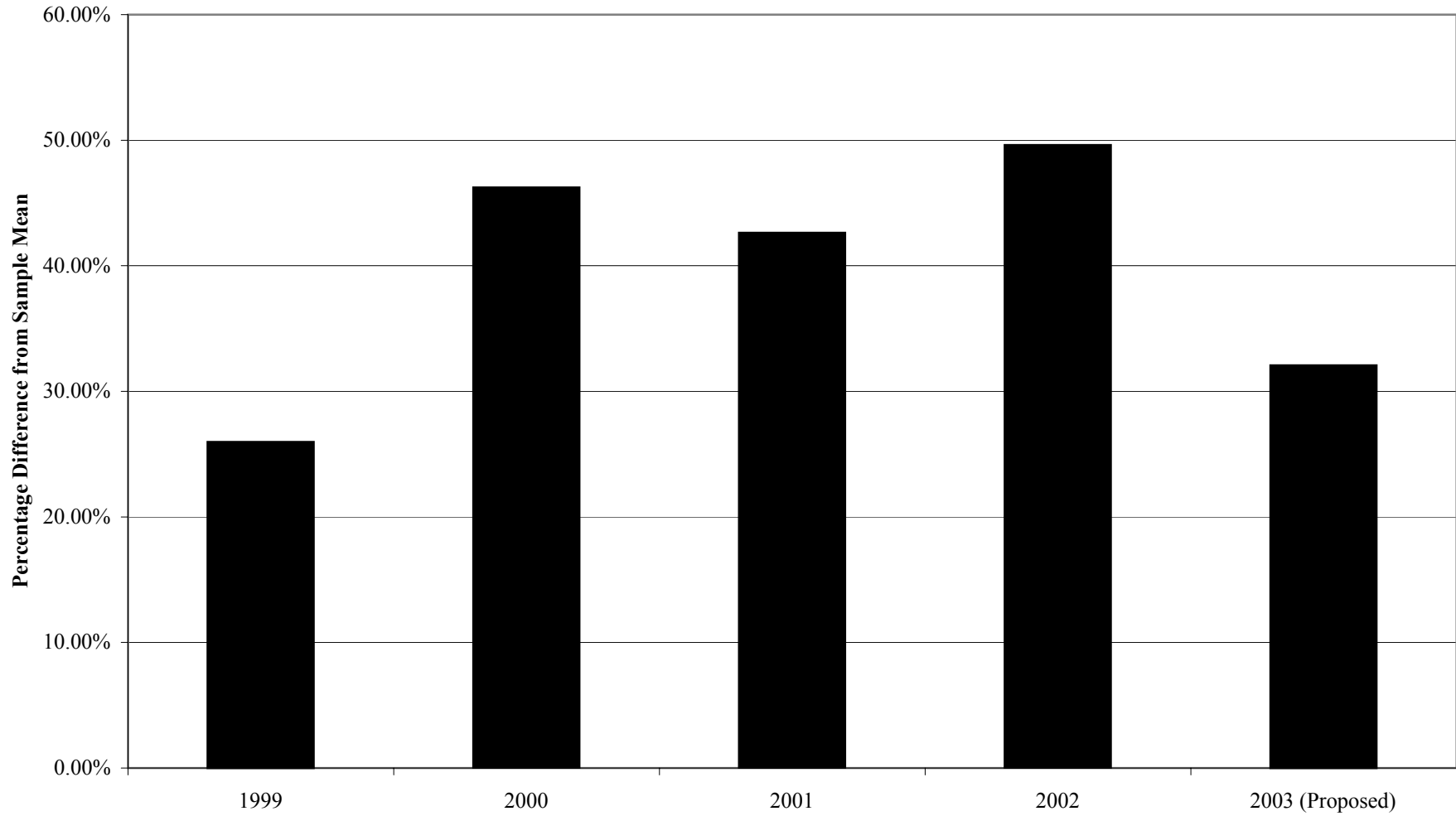
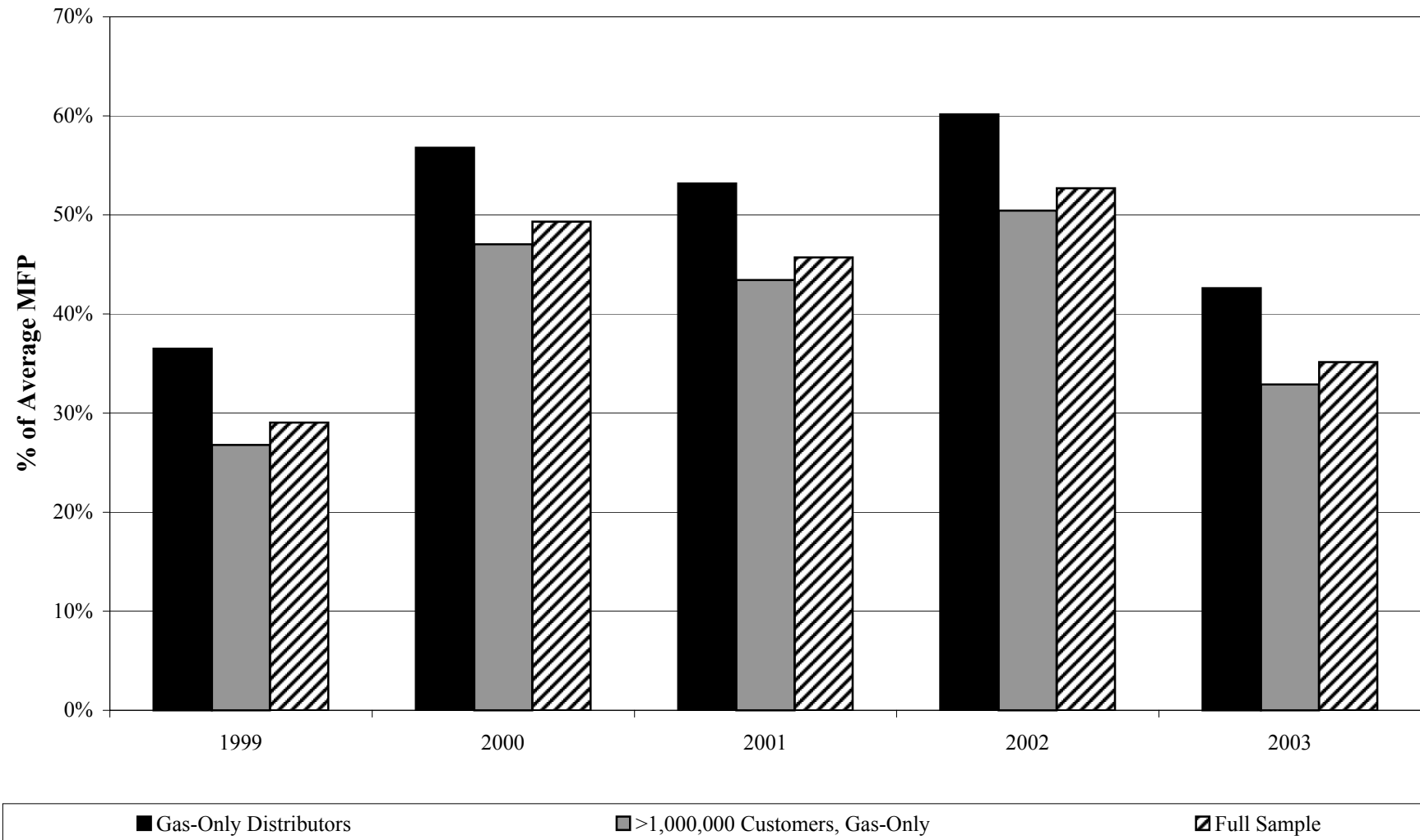


Figure 2

How Enbridge MFP Compares to Averages for Selected Peer Groups (Enbridge as % of Average MFP)



quantity implicit in its cost projection is only 2.08 times the mean. These numbers produce an MFP index 1.38 times the mean. The productivity implicit in the proposed Enbridge expenses is thus about 32% above the full sample mean. This performance would have placed Enbridge eleventh out of 78 companies were it added to the full sample, clearly a top quartile performance.

Table 3 presents MFP results for the sample subgroups that are useful peers in an Enbridge evaluation. The table shows that the MFP of Enbridge compared favorably to the mean for both subgroups in all four years of the historical 1999-2002 period. As for the 2003 test year numbers, we find that the productivity of Enbridge was an impressive 33% above the mean for large gas only utilities and 43% above the mean for all gas only utilities. Its hypothetical performance would rank it first out of eight (including Enbridge) large gas only utilities. The results suggest that the Company's 2003 test year expenses can be achieved only with superior cost management.

4. ECONOMETRIC RESEARCH

4.1 An Overview of the Method

This section provides a substantially non-technical account of the econometric approach to benchmarking employed in this study. Additional, more technical details of the work are reported in the Appendix.

A mathematical model called a cost function was specified. Cost functions represent the relationship between the cost of a utility and quantifiable business conditions in its service territory. Business conditions are defined as aspects of a company's operating environment that affect its activities but cannot be controlled.

Economic theory was used to guide cost model development. We posited that the actual total cost (C_i) incurred by company, i , in service provision is the product of minimum achievable cost (C_i^*) and an efficiency factor ($efficiency_i$). This assumption can be expressed logarithmically as

$$\ln C_i = \ln C_i^* + \ln efficiency_i. \quad [4]$$

The term \ln indicates the natural log of a variable.

According to theory, the minimum total cost of an enterprise is a function of the amount of work it performs and the prices it pays for capital, labor, and other production inputs. 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 amount of work performed.

Here is a simple example of a minimum total cost function for power distribution that conforms to cost theory.

$$\ln C = \alpha_0 + \alpha_1 \cdot \ln N_{i,t} + \alpha_2 \cdot \ln W_{i,t} + u_{i,t}. \quad [5]$$

For each firm i in year t , the variable $N_{i,t}$ is the number of customers that the company serves. It quantifies one dimension of the work that it performs. The variable $W_{i,t}$ is the

¹ The logarithm of the product of two variables is the sum of their individual logarithms.

wage rate that the company pays. The wage rate and number of customers are the measured business conditions in this cost function.

The term $u_{i,t}$ is the error term of the minimum cost function. This term reflects any errors in the specification of the model, including problems in the measurement of output and other business condition variables and the exclusion from the model of any relevant business conditions. It is customary to assume a specific probability distribution for the error term that is determined by additional parameters, such as mean and variance.

Combining the results of Equations [4] and [5] we obtain the following model of cost:²

$$\ln C_{i,t} = \alpha_0 + \alpha_1 \cdot \ln N_{i,t} + \alpha_2 \cdot \ln W_{i,t} + e_{i,t}. \quad [6]$$

Here the *actual* (not minimum) total cost of a utility is a function of the two measured business conditions. The terms α_0 , α_1 , and α_2 are model parameters. Their values are assumed to be constant across companies and over some period of time. The α_0 parameter captures the efficiency factor for the average firm in the sample as well as the value of α_0 from the minimum total cost function. The values of α_1 and α_2 determine the effect of the two measured business conditions on cost. If the value of α_2 is positive, for instance, an increase in wage rates will raise cost.

The term $e_{i,t}$ is the error term for equation [6]. We assume that it is a random variable. It includes the error term from the minimum total cost function. It also reflects the extent to which the Company's efficiency factor differs from the sample norm.

A branch of statistics called econometrics has developed procedures for estimating parameters of economic models. Cost model parameters can be estimated econometrically

² Here is the full logic behind this result:

$$\begin{aligned} \ln C_{i,t} &= \ln C_{i,t}^* + \ln \text{efficiency}_i \\ &= (\alpha_0 + \alpha_1 \cdot \ln N_{i,t} + \alpha_2 \cdot \ln W_{i,t} + u_{i,t}) + \ln \text{efficiency}_i \\ &= (\alpha_0 + \ln \text{efficiency}^{\text{average}}) + \alpha_1 \ln N_{i,t} + \alpha_2 \cdot \ln W_{i,t} \\ &\quad + [u_i + (\ln \text{efficiency}_i - \ln \text{efficiency}^{\text{average}})] \\ &= \alpha_0 + \alpha_1 \cdot \ln N_{i,t} + \alpha_2 \cdot \ln W_{i,t} + e_{i,t} \end{aligned}$$

using historical data on the costs incurred by utilities and on the business conditions they faced. For example, a positive estimate for α_2 would reflect the fact that the cost reported by sampled companies was typically higher when higher wages were paid to employees.

Numerous statistical methods have been established in the econometrics literature for estimating parameters of economic models. In choosing among these, we have been guided by the desire to obtain a good model for cost benchmarking. Econometric methods are useful in selecting business conditions for the model. Tests are available for the hypothesis that the parameter for a business condition variable equals zero. Variables were excluded from the model when such hypotheses could not be rejected.

4.2.2 O&M Cost Benchmarking

We use our econometric cost model to appraise Enbridge's O&M cost. Such an appraisal is based on an econometric O&M cost benchmark model. We develop this model by fitting an O&M cost function with econometric parameter estimates. The O&M cost function is based on that portion of total cost that is attributed to and explained by business condition variables that affect O&M activity. We use this model to predict a company's O&M cost given the values of the company's business condition variables that affect O&M activity.

Returning to our example, we might predict the (logged) O&M cost of Enbridge in period t as follows:³

$$\ln \hat{C}^{OM}_{Enbridge,t} = \hat{\alpha}_0 + \hat{\alpha}_1 \cdot \ln N_{Enbridge,t} + \hat{\alpha}_2 \cdot \ln W_{Enbridge,t} \quad [7]$$

Here $\hat{C}^{OM}_{Enbridge,t}$ denotes the predicted O&M cost of the Company in period t , $N_{Enbridge,t}$ is the number of customers it served, and $W_{Enbridge,t}$ is the wage rate that it paid. The $\hat{\alpha}_0$, $\hat{\alpha}_1$, and $\hat{\alpha}_2$ terms are parameter estimates.

If the parameter estimates are accurate and the value of the error term is zero, the percentage difference between the Company's actual O&M cost and that predicted by the

³ Since this is a predicted equation using estimated parameters there is no error term.

model is the percentage difference between the O&M efficiency factor of the Company and that of the sample mean firm.

$$\ln\left(\frac{C^{OM}_{Enbridge,t}}{\hat{C}^{OM}_{Enbridge,t}}\right) = \ln\left(\frac{efficiency_{Enbridge}}{efficiency_{average}}\right). \quad [8]$$

This percentage difference is a measure of the Company’s O&M cost performance.

An O&M cost prediction like that generated in the manner just described is our best *single* guess of the Company’s O&M cost given the business conditions that it faces. This is an example of a point prediction. An important characteristic of the econometric approach to O&M benchmarking is that the statistical results provide information about the *precision* of such point predictions. According to econometric theory, precision is greater to the extent that:

- The model is more successful in explaining the variation in O&M cost in the sample
- The size of the sample is larger
- The number of business condition variables included in the model is smaller
- The business conditions of sample companies are more varied
- The business conditions of the subject company are closer to those of the typical firm in the sample

We assess the precision of a company’s O&M cost prediction based on a routine application of forecast variance. This variance, which tells us about the statistical significance of our point prediction, is essentially the pre and post multiplication of the covariance matrix of the parameter estimates by a vector of the explanatory or business condition variables.

4.3 Econometric Results

Estimation results for the cost model are reported in Table 4. The parameter values for the additional business conditions and for the first order terms of the 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 critical value was 1.645. 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 plausibly signed and statistically significant parameter estimates. The parameters of the other variables (which were not translogged) were also required to have statistically significant estimates.

Examining the cost function results in Table 4, it can be seen that the parameter estimates were plausible as to sign and magnitude. With regard to the first order terms, cost was found to be higher the higher were input prices and output quantities. At the sample mean, a 1% increase in the number of customers raised cost by 0.70%. A 1% hike in

Table 4

Translog Cost Function Regression Results: Gas Delivery

Variable Key*

L= Labor Price
 K= Capital Price
 N= Number Customers
 V= Total Throughput
 NE= Number of Electric Customers
 CI= % Non-Iron and Unprotected Bare Steel in Distribution Miles
 Q= Earthquake Dummy
 F= Frost Depth Index
 T= Trend

Explanatory Variable	Estimated Coefficient	t-Statistic**	Explanatory Variable	Estimated Coefficient	t-Statistic**
WL	0.2047	41.36	NE	-0.0101	-8.06
LL	-0.0894	-2.34	NEL	-0.0004	-0.93
LK	-0.0311	-1.25	NEK	0.0026	5.51
LN	0.0180	2.21	CI	-0.1117	-3.81
LV	-0.0206	-2.54	CIL	-0.0493	-4.31
WK	0.6573	110.59	CIK	0.0509	3.87
KK	0.1427	4.71	Q	0.0087	1.72
KN	-0.0322	-3.40	QL	-0.0040	-2.46
KV	0.0298	3.08	QK	0.0035	1.73
N	0.7046	19.53	F	-0.0537	-2.60
NN	-0.3774	-4.16	FL	0.0049	0.74
NV			FK	0.0278	3.52
V	0.1695	4.94	T	-0.0041	-1.63
VV	-0.3954	-3.50	TL	-0.0068	-7.41
			TK	0.0066	6.00
			Constant	7.9692	450.89
			System Rbar-Squared		0.969
			Number of Observations		451

*Data for all variables were logged and mean-scaled prior to model estimations

**The Critical Value for t-Statistic is 1.645.

throughput raised cost by about 0.17%. The number of customers accounted for about 81% of the sum of the estimated output quantity elasticities. This figure was used in output quantity index construction. The number of customers served was clearly the dominant output-related cost driver.

Turning to results for the input prices, it can be seen that the elasticity of cost with respect to the price of capital services was 0.66%. This was more than three times the estimated elasticity of the price of labor. This comparison reflects the capital intensiveness of the gas distribution business.

The parameter estimates for the first order terms of the additional variables in the cost function were also sensible.

- Total cost was lower the greater was the percentage of distribution mains not made with cast iron and bare steel.
- Cost was lower the greater were the number of electric customers served by a distributor.
- Cost was higher the greater was maximum frost depth and earthquake risk.
- The estimate of the trend variable parameter was -0.41% and was highly significant. This suggests a gradual downward shift in the cost function.

4.4 O&M Benchmarking Results

Table 5 presents the results of our appraisal of Enbridge's O&M cost using the econometric model. The parameter estimates of the model are based on data from 1990-2000, while the company's predicted O&M cost is based on five years of data covering 1999-2003. Data for 2003 are projected business conditions and an O&M expense allowance of \$280.9 million, which includes an amount budgeted for demand side management⁴. The Company's average O&M cost during the five-year sample period is about 27% below its predicted value. The hypothesis that the company is an average (or inferior) cost performer was rejected at the 95% confidence level. This result ranks eighth best among the 41 sampled companies. Table 5 also presents the Company's O&M cost efficiency for the test year of 2003 based on the above noted O&M expense allowance. Given projections of business conditions that company would face, its predicted O&M cost is below the allowed O&M expense by 22%. This prediction is statistically significant at the 90% confidence level.

⁴ Source: Settlement Proposal, Filed 2003-03-14, RP-2002-0133, Exhibit 1N, Tab 1, Schedule 1.

Table 5

ACTUAL AND PREDICTED COST FOR GAS DISTRIBUTION

	Actual Cost \$1000	Predicted Cost \$1000	Difference (%)*	t-statistic
1999-2003	254,231	334,034	-27.3%	-1.686
2003	280,969	348,363	-21.5%	-2.144

* Percent difference based on natural logs.

APPENDIX:

FURTHER DETAILS OF THE BENCHMARKING RESEARCH

This Appendix provides additional and more technical details of our benchmarking work. We first consider details of index construction. There follows a discussion of the supporting econometric work.

A.1 Index Research

This section contains further details of our index research. Sub-Section 1.1 discusses the output quantity indexes. Sub-Section 1.2 discusses the formula for the input quantity indexes. Sub-Sections 1.3 and 1.4 address input price and quantity subindexes.

A.1.1 Output Quantity Level Indexes

The output quantity level index for each company i in the U.S. sample is defined by the formula

$$\ln \text{ Output Quantity}_{i,t} = \sum_h S_h^E \cdot \ln \left(\frac{Y_{i,h,t}}{\bar{Y}_{h,s}} \right) \quad [9]$$

Here in each period t ,

$Y_{i,h,t}$ = Quantity of output dimension h for company i

$\bar{Y}_{h,s}$ = Mean quantity of output dimension h used by all sampled utilities in base year s

S_h^E = Share of output dimension h in the sum of the econometric estimates of the cost elasticities of the output quantities.

The shares resulting from the econometric work for the number of customers and throughput were .81% and .19%, respectively. These shares reflect the result, discussed below, that the number of customers served was identified in the econometric work to be the dominant output-related cost driver. Recall that the base year was 2000. Results for Enbridge were computed analogously save that Enbridge figures were not used in the calculation of the sample mean.

A.1.2 Input Quantity Level Indexes

The input quantity level indexes used in the study for U.S. companies are of bilateral Tornqvist form. The formula for each such index may be stated formally as

$$\ln \text{Input Quantity}_{i,t} = \sum_j \frac{1}{2} \cdot (S_{i,j,t} + \bar{S}_{j,s}) \cdot \ln \left(\frac{X_{i,j,t}}{\bar{X}_{j,s}} \right) \quad [10]$$

Here in each year t ,

- $\text{Input Quantity}_{i,t}$ = Input quantity index for company i
- $X_{i,j,t}$ = Quantity of input j used by company i
- $\bar{X}_{j,s}$ = Mean quantity of input j used by all sampled companies in base year s
- $S_{i,j,t}^C$ = Share of input category j in the applicable O&M expenses of company i
- $\bar{S}_{j,s}^C$ = Mean share of input category j in the applicable total cost of all sampled companies in base year s .

It can be seen that each index is a weighted average of comparisons of the input quantities used by the subject company to the mean of the input quantities used by all sampled distributors. Each comparison takes the form of the logarithm of the ratio of the quantities. The weight assigned to each quantity comparison is the average of the cost share for the subject distributor and the corresponding mean of the cost shares for all sampled distributors. Results for Enbridge were computed analogously save that Enbridge figures were not used to compute the base year mean quantities or cost shares.

A.1.3 Input Prices

Input price indexes were used in input quantity index construction. The labor 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 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. For U.S. companies,

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.

The construction of a labor price index value for Enbridge involved several steps. For the years 1999 and 2000, we first calculated the ratio in that year of the average weekly earnings of a Canadian worker engaged in the utility industry to the corresponding average for the U.S. The data were obtained from BLS and Stats Canada. We next calculated the ratio of the average earnings of the population 15 years and over in Toronto in 1995 to the corresponding figure for Canada as a whole. These data were also obtained from Stats Canada. The labor price index value for Enbridge was then calculated as product of these two ratios and the average index value for the U.S. sample. For the years 2001 and 2002, we multiplied the average index value for the U.S. in those years to the same two ratios. For 2003, we updated the index number thus calculated using its 2002 value and the average annual growth rate of the Enbridge values from 1999 to 2002.

Prices for other O&M inputs were assumed to be the same in a given year for all U.S. companies. They were escalated by the U.S. gross domestic product price index. Our general approach to the computation of the price index for capital services, which was used in the econometric work, is described in Appendix Section 2.3.

The construction of the corresponding index value for Enbridge was undertaken as follows. We calculated the values for the 1999-2002 period as the product of the index just described and a purchasing power parity for the Canadian economy. The purchasing power parities were obtained from the OECD. The year 2002 is the latest for which they are as yet available. For the 2003 test year, we took the 2002 input price index value thus calculated and multiplied it by the average annual growth rate in the Enbridge values from 1999-2002.

A.1.4 Input Quantity Subindexes

Each quantity level subindex for labor was the ratio of salaries and wages to the labor price index discussed above. Each quantity level subindex for the miscellaneous other gas delivery O&M inputs was the ratio of non-labor O&M expenses to the corresponding price index, discussed above.

A.2 Econometric Research

A.2.1 Form of the Cost Model

The functional form selected for this study was the translog. This very flexible function is the most frequently used in econometric cost research, and is by some accounts the most reliable of several available alternatives.⁵ The general form of the cost function used in this study is:

$$\begin{aligned} \ln C = & \alpha_o + \sum_h \alpha_h \ln Y_h + \sum_j \alpha_j \ln W_j + \sum_k \alpha_k \ln Z_k + \alpha_t T \\ & + \frac{1}{2} \left[\sum_h \sum_m \gamma_{hm} \ln Y_h \ln Y_m + \sum_j \sum_n \gamma_{jn} \ln W_j \ln W_n \right] \\ & + \sum_h \sum_j \gamma_{hj} \ln Y_h \ln W_j + \sum_k \sum_j \gamma_{kj} \ln Z_k \ln W_j + \sum_j \gamma_{tj} T \ln W_j. \end{aligned} \quad [11]$$

Here, Y_h denotes any of several variables that quantify output, W_j denotes any of several input prices, and Z_k denotes any of several additional business conditions. T is a trend variable. Notice that to simplify the model the Z variables and the trend variable are interacted only with the input price variables and have no quadratic terms.

One aspect of the flexibility of this function is its ability to allow the elasticity of cost with respect to each business condition variable to vary with the possible values of that variable. The elasticity of cost with respect to an output quantity, for instance, may be greater at larger values of the variable than at smaller ones. This type of relationship between cost and quantity is often found in cost research.

Cost theory requires a well-behaved cost function to be linearly homogeneous in input prices. This implies the following three sets of restrictions:

$$\sum_j^N \frac{\partial \ln C}{\partial \ln W_j} = 1 \quad [12]$$

$$\sum_h^N \frac{\partial^2 \ln C}{\partial \ln W_h \partial \ln W_j} = 0 \quad \forall j = 1, \dots, N \quad [13]$$

⁵ See, for example, Guilkey (1983), et. al.

$$\sum_h^K \frac{\partial^2 \ln C}{\partial \ln Y_h \partial \ln Y_j} = 0 \quad \forall j = 1, \dots, K \quad [14]$$

Estimation of the parameters of the cost function 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:

$$S_j = \alpha_j + \sum_n \gamma_{jn} \ln W_n + \sum_h \gamma_{hj} \ln Y_h + \sum_k \gamma_{kj} \ln Z_k + \sum_j \gamma_{ij} T. \quad [15]$$

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. Furthermore, 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.2.2 Estimation Procedure

We used a “seemingly unrelated” regression procedure to estimate the cost function parameters that is due to Zellner (1962).⁶ 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.⁷ Since we estimated these unknown disturbance matrices consistently, the estimators we eventually computed are equivalent to Maximum Likelihood Estimation (MLE).⁸ 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

⁶ See Zellner, A. (1962)

⁷ That is, we iterate the procedure until the determinant of the differences between any two consecutive estimated disturbance matrices are approximately zero.

⁸ See Dhrymes (1971), Oberhofer and Kmenta (1974), Magnus (1978).

observation, one cost share equation is redundant and must be dropped.⁹ 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.

A.2.3 Capital Cost

Capital cost must, as discussed above, be calculated for use in cost model estimation. 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.¹⁰ It facilitates the use of benchmarking of cost data for utilities with different plant vintages.

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 ($XK_{j,t-1}$).

$$CK_{j,t} = WKS_{j,t} \cdot XK_{j,t-1}. \quad [16]$$

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.

In constructing capital quantity indexes we took 1985 as the benchmark or starting year. The values for these indexes in the benchmark year are based on the net value of plant as reported in the USR. We estimated the benchmark year (inflation adjusted) value of net plant by dividing this book value by a weighted average of the values of an index of utility construction cost for a period ending in the benchmark year. Values were considered for a series of consecutive years with length equal to the lifetime of the relevant plant category.

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

$$XK_{j,t} = (1-d) \cdot XK_{j,t-1} + \frac{VI_{j,t}}{WKA_{j,t}}. \quad [17]$$

⁹ This equation can be estimated indirectly if desired from the estimates of the parameters remaining in the model.

¹⁰ See Hall and Jorgensen (1967) for a seminal discussion of the service price method of capital cost measurement.

Here, the parameter d is the economic depreciation rate and VI_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 construction cost index (WKA_t) for each U.S. firm was the applicable regional Handy-Whitman index of utility construction costs for the relevant asset category. This was levelized using regional construction cost indexes from R.S. Means. The value of WKA for Enbridge for the years 1999-2000 was calculated as the average value of WKA for the U.S. firms in the sample times the ratio of the Toronto value of the Means index to the value for a 30 city average. For the 2001-2002 period, we escalated this by the trend in the Handy Whitman Index for the Northeast U.S. The value for the 2003 test year is the product of the value for 2002 thus calculated and the average annual growth rate of the Enbridge index thus calculated from 1999-2002.

The full formula for the capital service price index used in the econometric and MFP indexing work was:

$$WKS_{j,t} = d \cdot WKA_{j,j,t} + WKA_{j,t-1} \left[r_t - \frac{(WKA_{j,t} - WKA_{j,t-1})}{WKA_{j,t-1}} \right]. \quad [18]$$

The first term in this expression corresponds to the cost of depreciation. The second term corresponds to the real rate of return on capital. This term was smoothed to reduce capital cost volatility.

Here r_t is the opportunity cost of plant ownership per dollar of plant value. As a proxy for this we calculated for, U.S. companies, the user cost of capital for the U.S. economy using data in the National Income and Product Accounts (NIPA).¹¹ 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. The user cost of capital was computed analogously for the Canadian economy using Statistics Canada macroeconomic data.

¹¹ These data are reported in the *Handy-Whitman Index of Public Utility Construction Costs*, a publication of Whitman, Requardt and Associates.

A.2.4 Business Condition Variables

Input Price and Output Quantity Variables As noted above, economic theory suggests that the prices of production inputs and the quantities of work performed by utilities should be included in our cost model as business condition variables. The input price variables we employed were the price indexes discussed above in Appendix Section 1.3. There are two output quantity variables in our model: the number of retail customers and total throughput. We expect total cost to be higher the higher are the values of each of these workload measures.

Other Business Condition Variables Four additional business condition variables are included in the cost model. One is the percentage of distribution main not made of cast iron or unprotected bare steel. This is calculated from American Gas Association data. Cast iron pipes were common in gas system construction in the early days of the industry. They are still heavily used in older North American distribution systems, which tend to be eastern. Greater use of cast iron typically involves a combination of higher maintenance and replacement costs. A higher value for this variable means that a company has less cast iron and unprotected bare steel in its system.

A second additional business condition variable in this model is the number of power distribution customers served by the utility. This variable is intended to capture the extent to which the company has diversified into power distribution. Such diversification will typically lower cost due to the realization of scope economies. The extent of diversification is greater the greater is the value of the variable.

The third additional business condition variable in this model is an index of maximum frost depth. Distributors typically dig trenches for their mains deeper the deeper is the maximum frost depth. Maximum frost depth can also raise the cost of maintenance. Frost depth thus raises distribution cost. Our index has a higher value the less is the maximum frost depth.

The fourth and final extra business condition variable in the model is a measure of earthquake risk. The cost of system operation is apt to be greater the greater is the risk. Earthquake risk is greater the greater is the value of this variable.

The model also contains a trend variable. It permits predicted cost to shift over time for reasons other than changes in the specified business conditions. A trend variable captures the net effect on cost of diverse conditions, including technological change in the industry.

REFERENCES

- American Gas Association, Gas Facts, Arlington, VA, various issues.
- Breusch, T. and A.R. Pagan (1980), "The LaGrange Multiplier Test and Its Applications to Model Specification in Econometrics," *Review of Economic Studies*, 47 pages 239-54.
- Buse, A. (1982), "The Likelihood Ratio, Wald and LaGrange Multiplier Tests: An Expository Note," *The American Statistician*, 62 pages 153-7.
- Dhrymes, P.J. (1971), "Equivalence of Iterative Aitkin and Maximum Likelihood Estimators for a System of Regression Equations," *Australian Economic Papers*, 10 pages 20-4.
- Guilkey, et al. (1983), "A Comparison of Three Flexible Functional Forms," *International Economic Review*, 24 pages 591-616.
- Hall, R. and D.W. Jorgensen (1967), "Tax Policy and Investment Behavior," *American Economic Review*, 57 pages 391-410.
- Handy-Whitman Index of Public Utility Construction Costs, (1993), Baltimore, Whitman, Requardt and Associates.
- Hulten, C. and F. Wykoff (1981), "The Measurement of Economic Depreciation," in *Depreciation, Inflation, and the Taxation of Income From Capital*, C. Hulten ed., Washington D.C. Urban Institute.
- Magnus, J.R. (1978), "Maximum Likelihood Estimation of the GLS Model with Unknown Parameters in the Disturbance Covariance Matrix," *Journal of Econometrics*, 7 pages 281-312.
- Mundlak, Y. (1978), "On the Pooling of Time Series and Cross Section Data," *Econometrica*, 46 pages 69-85.
- Oberhofer, W. and Kmenta, J. (1974), "A General Procedure for Obtaining Maximum Likelihood Estimates in Generalized Regression Models," *Econometrica*, 42 pages 579-90.
- OECD (2002), *Purchasing Power Parities and Real Expenditures*, Paris, France.
- Platts/OPRI (2002), *Natural Gas LDC Database*, Boulder, CO.
- R.S. Means (1999), *Heavy Construction Cost Data*, Kingstton, MA.

Statistics Canada Official Website.

U.S. Department of Commerce, Bureau of Economic Analysis Official Website.

U.S. Department of Labor, Bureau of Labor Statistics Official Website.

Varian, H. (1984), *Microeconomic Analysis*, Norton and Company.

Zellner, A. (1962), "An Efficient Method of Estimating Seemingly Unrelated Regressions and Tests of Aggregation Bias," *Journal of the American Statistical Association*, 57 pages 348-68.