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EFFICIENCY, EQUITY AND REGULATION:

BELL CANADA

Interim Report

File #: 03SU.36100-9-9529

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PART 1 BACKGROUND STUDIES

In this section we report on four background studies which were undertaken at the beginning of this project with the goals of summarizing past research and clarifying the empirical directions to be taken during this project. In particular, in previous works we had been simultaneously examining multi-input multi-output cost and production models of the Bell Canada production process. As well, one of the guiding assumptions had been that the regulatory process had had its principal effect through setting the price of local services and that the rate of return constraint faced by Bell was of secondary importance. The background studies summarized here led to the conclusion that continued research effort should not be directed towards estimation of multi-output production functions. As well, considerable support was generated for the assumption that rate of return regulation was not binding.

The discussion of the background work is presented in the following two sections. The major findings and inter-relationships of the studies are summarized. The actual background studies are included as Appendices 1,2,3 and 4.

STUDIES RELATED TO THE USE OF COST AND PRODUCTION FUNCTIONS IN THE STUDY OF TECHNOLOGIES

The following two background papers cast light upon the issues involved in the specification of technologies:

1) More Pitfalls in the Testing of Duality Theory (Breslaw & Smith)
2) A Micro Test of the Neoclassical Production Theory (Breslaw, Corbo and Smith)

The Pitfalls paper demonstrates two important results. The first is that one output translog cost functions provide a more general specification of production technologies than do standard one output translog production functions. This result arises from the fact that one output production functions usually explicitly specify output as the dependent variable (ie. output is functionally dependent on inputs). In functional notation, output is the left-hand-side variable and the right-hand-side of the production relation consists of a function of the inputs, viz;

(1.1) $q = f(X)$ where: X is a vector of inputs
: q is output
: f is the production function

However, in the above case, output is explicitly separable from inputs. This separability is not encountered in the standard cost function specification:

(1.2) $C = C(r,q)$ where: C is cost
: r is a vector of input prices
: q is output

The importance of the separability issue can only be assessed empirically. To this end, translog-based models corresponding to the separable production model (1) and non-separable cost model (2) were estimated. It was noted that the cost model was much more robust than the production model. Thus, one should feel much more confident using cost model estimates of technology in the one output case. As well, one has now both theoretical and empirical grounds for less concern over the Appelbaum and Burgess results that (separable) production and (non-separable) cost models provide dissimilar estimates of characteristics of the aggregate US economy.

Two important additional results were generated in the Pitfalls paper. The first was that only in the case of one output homogeneous production functions could a non-separable production function model be estimated uniquely. The second, and related result is that multi-output production functions cannot be reliably estimated. The intuition behind this result lies in the fact that multi-output production surfaces (and, in fact, non-separable single output production surfaces) must be specified in implicit form as:

(3) $F(\overline{q},X) = 0$ where: $\overline{q}$ is the output vector
: X is the input vector

However, for practical estimation purposes (for example, a trans-log approximarion of F) a dependent variable must be specified and it is straightforward to show that (a) there is no natural choice of a dependent variable and (b) estimated properties of the underlying technology will change with every different dependent variable.

The Micro Test paper empirically demonstrates at the level of a firm (as opposed to the aggregate economy level) that one cannot reject the neoclassical model that the production function is related to the optimal choice of inputs (or, side-order marginal rate of technical substitution optimality conditions). This result is important since it differs from the aggregate US results of Appelbaum and it therefore supplies some support for the neoclassical view that production functions and optimization behaviour provide a reasonable vehicle for approximating technologies and decision making within firms. These results however can be questioned given that the production function used was separable between inputs and outputs.

STUDIES RELATED TO THE IMPORTANCE OF RATE OF RETURN CONSTRAINT IN BELL DECISION MAKING

The following two studies examine issues related to the modeling of rate of return constraint and the empirical importance of such a constraint in studying the Bell Canada production process:

1) The Restrictiveness of Flexible Functional Forms in the Modeling of Regulatory Constraint (Breslaw, Corbo and Smith)

2) A Direct Test of the A-J Effect: The Case of Bell Canada (Breslaw, Corbo and Smith)

In the Restrictiveness paper it is shown that second-order approximate cost functions are not suitable in general for modeling rate of return constraint. The problems arise from the fact that rate of return constraint (when it is binding) implies that the optimal factor mix is independent of the user cost of capital. The regulated firm will instead make its factor decisions with respect to the allowed rate of return - the maximum allowed cost of capital. However, this independence result implies a set of derivative restrictions upon the cost function. Unless factor shares are effectively constant, the standard second-order approximate cost functions will not satisfy these additional implied constraints.

There are three approaches to the solution of this problem.

First, it can be shown that a third-order approximation is sufficiently flexible to incorporate the additional restrictions. Unfortunately, the number of parameters to be estimated increases geometrically with the order of approximation and this leads to, at present, insurmountable computational problems in the general case.

Secondly, it is possible to impose the regulatory constraint conditions only at the mean of the sample. It was decided that such an approach would not be desirable given that any conclusions drawn are only valid at the mean.

Finally, it is possible to design a test of rate of return constraint by using a production function approach. The results of this approach are reported in the A-J paper summarized below.

Within a production model of a cost minimizing firm, the effect of a rate of return constraint can be examined in terms of the Lagrange multiplier associated with the constraint. However, it is not a straightforward matter to estimate this Lagrange multiplier from time series data. The problem arises from the fact that the multiplier will differ from year to year and even without taking account of the parameters of the production models, there are as many Lagrange multiplier parameters as data points, and hence it is not reasonable to specify the multiplier as a single parameter. Thus, a modified method must be introduced in order to assess the impact of a regulatory rate of return constraint.

To this end, an iterative technique (similar to one advanced by Houthakker) was used to estimate the Lagrange multipliers. Since a straightforward technique was not available for analyzing the individual significance of the multipliers, a series of simulation experiments were designed in order to assess the performance of the model when the inputs were endogeneous and the rate of return constraint was part of the simulated system. Two regimes were utilized- the allowed rate of return being the specified level, and the rate being the actual level. In every case the tracking with the rate of return constraint was inferior to the tracking when the Lagrange multiplier was constrained zero. Hence the A-J effect was rejected.

PART 2 EXTENSION OF THE 1978-1979 COST MODEL TO THREE OUTPUTS

Section 2.1

In this section we formally describe a more general cost model of the Bell Canada production process. The 1978-1979 IAER Project model has been extended to the case of three outputs - local services, message toll services and competitive services. In what follows the form of the cost model is specified. It will be noted that profit maximizing behaviour is assumed for two of the service outputs - message toll and competitive. It is assumed that regulation results in Bell satisfying demand for local services at the regulated price.

The Cost Model

It is assumed that the specified translog cost function is an approximation of the cost function resulting from the problem of finding that factor mix which minimizing a given output vector. In particular, it is assumed that cost is related to the factor prices, output and technology by the functional form given in equation 2.1. The definitions of all variables introduced can be found in Table 2.1.

Since the cost function results from a minimization problem, there are properties associated with the cost function consistent with the minimization process. In particular, the cost function must be homogeneous of degree one and concave in factor prices. The concavity property can be expressed in terms of determinants of minors of the factor price Hessian of the cost function. Concavity is not a universal property of translog cost functions and must therefore be verified at each data point.

TABLE 2.1

VARIABLE DEFINITIONS

C	=	total cost in current dollars = wL+rK+vM
L	=	weighted man hours with weights given by the 1967 wage structure
W	=	wage rate = total wage bill divided by L
K	=	net capital stock in 1967 dollars
r	=	user cost of capital derived using the Hall and Jorgenson (1971) formula and allowing for capital gains
M	=	index of raw materials, supplies and uncollectables in 1967 dollars
v	=	price index of raw materials
T	=	technology index of switching and accessability to the system
QL	= =	quantity index of local services in 1967 dollars
PQL	=	price index of local services (1967=1)
QM*	=	quantity index of intra territory adjacent, trans-Canada, US and Overseas message toll services in 1967 dollars
PQM	=	price index of message toll service (1967=1)
QT*	=	quantity index of intra territory, adjacent, trans-Canada, US and Overseas competitive toll services
PQT	=	price of competitive toll services (1967=1)

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* In the 1978-1979 IAER REPORT, WATS services were included in QT and price information did not exist to properly allocate them to QM. This data is now available. However, for consistency with past reports the results of using both new and old definition of QM and QT have been presented.

CHART 2.1

Equation 2.1 3 INPUT - 3 OUTPUT (SYMMETRIC) TRANSLOG COST FUNCTION

$$
\begin{aligned}
\ell nC = CC_o \; + \; & C_w \ell nw + C_r \ell nr + C_v \ell nv + C_T \ell nT + C_{QL} \ell nQL + C_{QM} \ell nQM + C_{QT} \ell nQT \\
& + \tfrac{1}{2}\ell nw \left[C_{ww} \ell nw + C_{wr} \ell nr + C_{wv} \ell nv + C_{wT} \ell nT + C_{wQL} \ell nQL + C_{wQM} \ell nQM + C_{wQT} \ell nQT \right] \\
& + \tfrac{1}{2}\ell nr \left[C_{wr} \ell nw + C_{rr} \ell nr + C_{rv} \ell nv + C_{rT} \ell nT + C_{rQL} \ell nQL + C_{rQM} \ell nQM + C_{rQT} \ell nQT \right] \\
& + \tfrac{1}{2}\ell nV \left[C_{wv} \ell nw + C_{rv} \ell nr + C_{vv} \ell nv + C_{vT} \ell nT + C_{vQL} \ell nQL + C_{vQM} \ell nQM + C_{vQT} \ell nQT \right] \\
& + \tfrac{1}{2}\ell nT \left[C_{wT} \ell nw + C_{rT} \ell nr + C_{vT} \ell nv + C_{TT} \ell nT + C_{QLT} \ell nQL + C_{QMT} \ell nQM + C_{QTT} \ell nQT \right] \\
& + \tfrac{1}{2}\ell nQL \left[C_{wQL} \ell nw + C_{rQL} \ell nr + C_{vQL} \ell nv + C_{QLT} \ell nT + C_{QLQL} \ell nQL + C_{QMQL} \ell nQM + C_{QTQL} \ell nQT \right] \\
& + \tfrac{1}{2}\ell nQM \left[C_{wQM} \ell nw + C_{rQM} \ell nr + C_{vQM} \ell nv + C_{QMT} \ell nT + C_{QMQL} \ell nQL + C_{QMQM} \ell nQM + C_{QMQT} \ell nQT \right] \\
& + \tfrac{1}{2}\ell nQT \left[C_{wQT} \ell nw + C_{rQT} \ell nr + C_{vQT} \ell nv + C_{QTT} \ell nT + C_{QTQL} \ell nQL + C_{QMQT} \ell nQM + C_{QTQT} \ell nQT \right]
\end{aligned}
$$

Alternatively, homogeneity of degree one in factor prices (or equivalently, addition of the derived factor share equations to unity) can be directly imposed by parameter restrictions. These restrictions can be deduced from the factor shares presented as equations 2.2, 2.3 and 2.4. These factor shares reflect Sheppard's Lemma which states that the partial derivatives of a cost function with respect to a factor prices must equal the cost minimizing factor input demands. Vertically adding equations 2.2, 2.3 and 2.4 we note the following eight independent restrictions implied by homogeneity:

$$R_1: \quad C_w + C_r + C_v = 1$$

$$R_2: \quad C_{ww} + C_{wr} + C_{wv} = 0$$

$$R_3: \quad C_{wr} + C_{rr} + C_{rv} = 0$$

$$R_4: \quad C_{wv} + C_{rv} + C_{vv} = 0$$

$$R_5: \quad C_{wT} + C_{rT} + C_{vT} = 0$$

$$R_6: \quad C_{wQL} + C_{rQL} + C_{vQL} = 0$$

$$R_7: \quad C_{wQM} + C_{rQM} + C_{vQM} = 0$$

$$R_8: \quad C_{wQT} + C_{rQT} + C_{vQT} = 0$$

Profit Maximization Conditions

The assumption of profit maximization in the provision of message toll and competitive services implies that marginal cost of each service is equated to its respective marginal revenue. A convenient way of writing this condition for a translog cost function is in terms of value of marginal revenue share equations. These equations are presented in equations 2.5 and 2.6 where MR_i is the marginal revenue of the i^{th} service.

DERIVED COST MINIMIZING FACTOR SHARE EQUATIONS

2.2 $$\frac{wL}{C} = C_{w} + C_{ww}\ell nw + C_{wr}\ell nr + C_{wv}\ell nv + C_{wT}\ell nT + C_{wQL}\ell nQL + C_{wQM}\ell nQM + C_{wQT}\ell nQT$$

2.3 $$\frac{rK}{C} = C_{r} + C_{wr}\ell nw + C_{rr}\ell nr + C_{rv}\ell nv + C_{vT}\ell nT + C_{rQL}\ell nQL + C_{rQM}\ell nQM + C_{rQT}\ell nQT$$

2.4 $$\frac{vM}{C} = C_{v} + C_{wv}\ell nw + C_{rv}\ell nr + C_{vv}\ell nv + C_{vT}\ell nT + C_{vQL}\ell nQL + C_{vQM}\ell nQM + C_{vQT}\ell nQT$$

DERIVED PROFIT MAXIMIZING VALUE OF MARGINAL REVENUE SHARE EQUATIONS

2.5 $$\frac{MR_{QM}\cdot QM}{C} = C_{QM} + C_{wQM}\ell nw + C_{rQM}\ell nr + C_{vQM}\ell nv + C_{QMT}\ell nT + C_{QMQL}\ell nQL + C_{QMQM}\ell nQM + C_{QMQT}\ell nQT$$

2.6 $$\frac{MR_{QT}\cdot QT}{C} = C_{QT} + C_{wQT}\ell nw + C_{rQT}\ell nr + C_{vQT}\ell nv + C_{QTT}\ell nT + C_{QTQL}\ell nQL + C_{QMQT}\ell nQM + C_{QTQT}\ell nQT$$

Summary Information and Statistics

Following estimation of the cost model and verification of the relevant concavity and profit maximization well-behavedness conditions, properties of the cost model are examined with a goal to understanding characteristics of the Bell production process. In particular, marginal costs, cost complementarities, ray scale economies, economies of scope, own and cross factor demand elasticities as well as elasticities of substitution are examined. As well, sensitivity analysis is applied to the model. The formulae for the summary statistics are given by equations 2.7 - 2.25. It will be noted that a sufficient condition for economies of scope between two services is that ray scale economies are significantly greater than unity and cost complementarities are significantly negative.

CHART 2.2

TECHNOLOGY SUMMARY STATISTICS EQUATIONS

Marginal Cost Equations

2.7 (LOCAL SERVICES)
$$MC_{QL} = \left(\frac{C}{QL}\right)\left[C_{QL} + C_{wQL}\ell nw + C_{rQL}\ell nr + C_{vQL}\ell nv + C_{QLT}\ell nT + C_{QLQL}\ell nQL + C_{QMQL}\ell nQM + C_{QTQL}\ell nQT\right]$$

2.8 (MESSAGE TOLL SERVICES)
$$MC_{QM} = \frac{C}{QM}\left[C_{QM} + C_{wQM}\ell nw{+}{+}\ C_{rQM}\ell nr + C_{vQM}\ell nv + C_{QMT}\ell nT + C_{QMQL}\ell nQL\ \ C_{QMQM}\ell nQM + C_{QMQT}\ell nQT\right]$$

2.9 (COMPETITIVE SERVICES)
$$MC_{QT} = \frac{C}{QT}\left[C_{QT} + C_{wQT}\ell nw + C_{rQT}\ell nr + C_{vQT}\ell nv + C_{QTT}\ell nT + C_{QTQL}\ell nQL\ \ C_{QMQT}\ell nQM + C_{QTQT}\ell nQT\right]$$

Cost Complementarity Formulae

2.10 LOCAL - MESSAGE TOLL
$$\frac{\partial MC_{QL}}{\partial QM} = \frac{MC_{QL}\cdot MC_{QM}}{C} - \frac{C_{QMQL}\cdot C}{QL.QM}$$

2.11 LOCAL - COMPETITIVE
$$\frac{\partial MC_{QL}}{\partial QT} = \frac{MC_{QL}\cdot MC_{QT}}{C} - \frac{C_{QTQL}\cdot C}{QL.QT}$$

2.12 MESSAGE TOLL - COMPETITIVE
$$\frac{\partial MC_{QM}}{\partial QT} = \frac{MC_{QM}\cdot MC_{QT}}{C} - \frac{C_{QMQT}\cdot C}{QM.QT}$$

Ray Scale Economies (Inverse of Ray Cost Elasticity)

2.13 SCALE
$$SCALE = \left[\frac{MC_{QL}\cdot QL}{C} + \frac{MC_{QM}\cdot QM}{C} + \frac{MC_{QT}\cdot QT}{C}\right]^{-1}$$

Cost Minimizing Factor Demands

$$2.14 \quad L^* = \frac{\partial C}{\partial w} = \left(\frac{C}{w}\right)\left[C_w + C_{ww}\ln w + C_{wr}\ln r + C_{wv}\ln v + C_{wT}\ln T + C_{wQL}\ln QL + C_{wQM}\ln QM + C_{wQT}\ln QT\right]$$

$$2.15 \quad K^* = \frac{\partial C}{\partial r} = \left(\frac{C}{r}\right)\left[C_r + C_{wr}\ln w + C_{rr}\ln r + C_{rv}\ln v + C_{rT}\ln T + C_{rQL}\ln QL + C_{rQM}\ln QM + C_{rQT}\ln QT\right]$$

$$2.16 \quad M^* = \frac{\partial C}{\partial v} = \left(\frac{C}{v}\right)\left[C_v + C_{wv}\ln w + C_{rv}\ln r + C_{vv}\ln v + C_{vT}\ln T + C_{vQL}\ln QL + C_{vQM}\ln QM + C_{vQT}\ln QT\right]$$

Factor Price Elasticities

2.17 (Labour-Labour) $E_{LL} = \frac{\partial^2 C}{\partial w^2} . \frac{w}{L}$

2.18 (Labour-Capital) $E_{LK} = \frac{\partial^2 C}{\partial w \partial r} . \frac{r}{L}$

2.19 (Labour-Materials) $E_{LM} = \frac{\partial^2 C}{\partial w \partial v} . \frac{v}{L}$

2.20 (Capital-Capital) $E_{KK} = \frac{\partial^2 C}{\partial r^2} . \frac{r}{K}$

2.21 (Capital-Materials) $E_{KM} = \frac{\partial^2 C}{\partial r \partial v} . \frac{v}{K}$

2.22 (Materials-Materials) $E_{MM} = \frac{\partial^2 C}{\partial v^2} . \frac{v}{M}$

Elasticities of Substitutes

2.23 (Labour-Capital) $S_{LK} = \frac{E_{LK}.C}{r.K}$

2.24 (Labour-Materials) $S_{LM} = \frac{E_{LM}.C}{v.M}$

2.25 (Capital-Materials) $S_{KM} = \frac{E_{KM}.C}{v.M}$

Section 2.2 ESTIMATION OF THE COST MODEL

The cost model described in the previous section was estimated using the same data as in the 1978-1979 IAER Report. Demand elasticity estimated from the 1978-1979 IAER Report were introduced as extranenous information in order to calculate the marginal revenue series for the estimation of equations (2.5) and 2.6. The following formula was used to calculate the marginal revenue series:

$$2.26 \qquad MR_i = P_i\left[1 + \frac{1}{\varepsilon_i}\right]$$

i = Message Toll, competitive services

$\varepsilon_{MT} = 1.40124$

$\varepsilon_{OT} = -1.71972$

For the estimation, restrictions R_1 to R_8 imply that one factor share equation must be dropped. Singularity of the variance-covariance matrix would otherwise result. The materials equation (2.4) was dropped and the parameters were later residually calculated along with their standard errors. A full information maximum likelihood algorithm was used iteratively until the parameter estimates converged - thereby guaranteeing that the estimated coefficients would be independent of the dropped share equation.

The estimated coefficients and their asymptotic standard errors are presented in Table 2.2. Additional equation by equation information is presented in Table 2.3.

Discussion

It will be noted that the estimated model fits quite tightly. As well, the cost function was verified to be concave at every data point. The model leads to many interesting insights into the underlying technology of the Bell Canada production process. These results are presented in the following abbreviated form:

TABLE 2.2

PARAMETER ESTIMATES OF THE 3-INPUT 3-OUTPUT COST MODEL

PARAMETER	ESTIMATE	ASYMPTOTIC STANDARD ERROR
CC_o	.0006	.006
C_w	.3313*	.0036
C_r	.4792*	.0034
C_v	.1895*	.0020
C_T	-.5352*	.1160
C_{ww}	-.1231*	.0387
C_{wr}	.0877*	.0312
C_{wv}	.0354	.0214
C_{wT}	-.3225*	.0460
C_{rr}	-.0080	.0338
C_{rv}	-.0797*	.0174
C_{rT}	.3732*	.0496
C_{vv}	.0443*	.0196
C_{vT}	-.0507*	.0249
C_{TT}	.3040	1.8814
C_{QL}	.7144*	.0613
C_{QM}	.0972*	.0015
C_{QT}	.0322*	.0005
C_{QLQL}	.2535	.5678
C_{QMQL}	-.0133	.0201
C_{QTQL}	-.0603*	.0059
C_{QLT}	-.6155*	.3117
C_{QMQM}	-.0129	.0105
C_{QMQT}	.0157*	.0030

TABLE 2.2. (continued)

PARAMETER	ESTIMATE	ASYMPTOTIC STANDARD ERROR
C_{QMT}	.0174	.0127
C_{QTQT}	.0197*	.0012
C_{QTT}	.0364	.7135
C_{WQL}	-.1921*	.0406
C_{WQM}	-.0401	.1253
C_{WQT}	-.0151*	-.0049
C_{RQL}	-.2335*	.0377
C_{RQM}	.0467*	.0128
C_{RQT}	.0224*	.0053
C_{vQC}	.0415	.0237
C_{vQM}	-.0066	.0101
C_{vQT}	-.0073*	.0036

*significant at the 95% confidence level

TABLE 2.3

ADDITIONAL EQUATION INFORMATION

EQUATION		R^2	D.W.	SSR
Cost Function	2.1	.9997	1.578	.0033
Labour Share	2.2	.9800	.9432	.0018
Capital Share	2.3	.9771	1.1600	.0021
Toll Profit	2.5	NA	1.0323	.0001
Competitive Profit	2.6	NA	.8925	.00002

(1) Marginal cost of local services exceeds the price of local services at every data point.

(2) The inverse of the cost elasticity is significantly greater than unity indicating the existence of scale economies. In 1967 the scale measure was 1.22 but by 1976 it had increased to 1.36. The scale elasticity is not strongly trended.

(3) Scope economies exist between local and competitive services. There is insufficient evidence to deduce the existence of scope economies between local and message toll services and message toll and other services. In absolute terms, the marginal cost of any one service is not strongly affected by outputs of other services.

(4) The elasticity of substitution between labour and capital and labour and materials are both approximately 1.5 - indicating that these pairs of factors can be substituted with some ease (at least more easily than for US manufacturing where the average elasticity of substitution is unity).

(5) The elasticity of substitution between capital and materials indicates that these factors are complementary for the early part of the sample and weak substitutes thereafter.

(6) Labour as a factor input is becoming more elastically demanded over time to a value of -1.16 in 1976 whereas the factor price elasticities of capital and materials are stable in the range of -5 throughout most of the sample.

Conclusions

The results of the three output cost model are quite consistent with those presented for the two output (message toll and local aggregated) cost model presented in the 1978-1979 IAER Report. It would appear reasonable to conclude that the profit maximization assumption for message toll services does not conflict with the data. Thus, from a preliminary standpoint, there appears to be some scope for additional policy analysis using the message toll cost information supplied by this model.

Sensitivity Analysis

The model presented above was subjected to two forms of sensitivity analysis.

First, the extraneous price elasticity estimates were introduced in a 10% confidence band about the point estimate values. The model remained well-behaved and stable and, although the scale elasticity changed (as equation 2.13 would suggest) there was a remarkable stability in the elasticity of substitution estimates as well as factor demand properties.

Secondly, the index of technology was subjected to two monotonic transformations - logarithmic and exponential. As expected, under the exponential transformation, scale economies declined whereas the logarithmic transformation led to greater scale economies. In both of these cases a trend was introduced. These results suggest that the scale-technology trade-off remains a shadowy area. The stability of scale estimates implied by the existing measure suggests that its usage be retained. However, sensitivity analysis must be undertaken before any policy conclusions can be reached at further stages of the research.

PART 3 A RE-EXAMINATION OF THE 1978-1979 FINAL DEMAND MODEL

A number of features of the 1978-1979 demand model suggested that it might be profitably re-examined before construction a demand model with the newly available data (WATS prices and business-residential disaggregation of local and message toll prices). In particular, the 1978 model required large and strongly significant serial correlation parameters for local and competitive services. As well, the equation by equation point estimates of the model differed from the full simultaneous equation model. Finally, structural demand change as characterized by dummy variables for 1959 and 1970 onward in the message toll equation were not completely explained.

The analysis undertaken this year led to some very interesting findings. In particular, it was found that individual demand equations were quite unstable in the first three years of the sample. This instability, characterized by spurious serial correlation and large shifts in point estimates disappeared if the first three observations were dropped and if account was taken of the structural change induced in competitive services demand due to the inclusion of WATS. The reformulated model does <u>not</u> require correction for serial correlation and the equation by equation point estimates are almost identical to the system estimates. It would appear then that the new model yields an important increase in explanatory power over the 1978-1979 model.

The equations of the 1978-1979 IAER demand model are given in Chart 3.1. Tables 3.1 and 3.2 demonstrate that the autoregressive corrections played a very important role and that there was considerable changes in the price elasticity estimates for competitive services from the single demand equation to the entire demand system. It will also be noted that without the autoregressive correction the price elasticities of local and other toll were positive.

The equations of the reformulated model are presented in Chart 3.2. In both the local and message toll equations two dummy variables are introduced - D_{59} which corresponds to any taste shifts occasioned by the increased availability and importance of direct distance dialing capabilities and D_{70} which corresponds to the restructuring of tariffs for long distance calls to a mimimum of one minute. It was also argued last year that D_{59} and D_{70} corresponded as well to discrete jumps in the tariff schedules for local and message toll services. This argument remains valid.

The message toll equation was determined to have an important structural change in 1964. After 1964, the year when WATS started to become a major component of competitive services, the constant term, price elasticity and income elasticity all shifted. The dummy variable D_{64} provides for this change in the specified equations. The double-subscripted parameters are in effect for the early part of the sample while for 1964 onwards, the appropriate parameters are C_o, C_1 and C_2. The structural change in 1959 and 1970 in the local and message toll equations did not lead to any changes in the income or price elasticities for these services.

The model described in Chart 3.2 was estimated for the sample period starting in 1953 and then for 1954 and so on. It was determined that the parameter estimates with sample periods beginning with 1955 and later were quite stable, whereas the larger sample

CHART 3.1

1978-1979 IAER Demand Model

LOCAL SERVICES

2.27 $$\ell n\left(\frac{QL}{POP}\right) = A_o + A_1\ \ell n\left(\frac{PQL}{CPI}\right) + A_2\ \ell n\left(\frac{YD}{CPI.POP}\right) \quad ; \rho_A$$

MESSAGE TOLL SERVICES

2.28 $$\ell n\left(\frac{QT}{POP}\right) = B_o + B_1\ \ell n\left(\frac{PQM}{CPI}\right) + B_2\ \ell n\left(\frac{YD}{CPI.POP}\right) + BD_1 \cdot D_{59} + BD_2 \cdot D_{70} \quad ; \rho_B$$

COMPETITIVE SERVICES

2.29 $$\ell n\left(\frac{QT}{POP}\right) = C_o + C_1\ \ell n\left(\frac{PQT}{CPI}\right) + C_2\ \ell n\left(\frac{YD}{CPI.POP}\right) \quad ; \rho_C$$

where: POP= population in Quebec and Ontario

CPI= consumer price index (1967=1)

YD= disposible income in Ontario and Quebec

ρ_A, ρ_B, ρ_C= the autoregressive error structure parameter corresponding to the demand equations.

TABLE 3.1

PARAMETER ESTIMATES OF THE 1978-1979 IAER MODEL NO AUTOREGRESSIVE ERROR STRUCTURE*

Parameters	Equation by Equation			System
	LOCAL	MESSAGE	COMPETITIVE	
A_o	-5.681			-5.724
A_1	.238			.292
A_2	1.777			1.812
B_0		-5.513		-6.314
B_1		-1.186		-.595
B_2		1.014		1.747
BD_1		.140		.015
BD_2		.083		.033
C_o			-13.38	-17.134
C_1			1.75	5.515
C_2			6.06	9.115
LOG OF LIKELIHOOD FUNCTION				
LOCAL	30.05			
MESSAGE		48.13		127.70
COMPETITIVE			-5.27	
D.W.				
LOCAL	.5627			.589
MESSAGE		1.121		.746
COMPETITIVE			.347	.687

* The standard errors have been suppressed but are shown on the computer printouts to be supplied.

TABLE 3.2

PARAMETER ESTIMATES OF THE 1978-1979 IAFR MODEL

AUTOREGRESSIVE ERROR STRUCTURES*

Parameters	Equation by Equation			System
	LOCAL	MESSAGE	COMPETITIVE	
A_o	1.335			2.413
A_1	-.196			-.155
A_2	.153			.167
ρ_A	.991			.992
B_o		-5.056		-5.190
B_1		-1.142		-1.401
B_2		.686		.775
BD_1		.090		.114
BD_2		.117		.099
ρ_B		.703		.576
C_o			-6.915	-7.865
C_1			-.942	-1.720
C_2			1.414	1.785
ρ_C			.893	.812
LOG OF LIKELIHOOD FUNCTION				
LOCAL	77.22			
MESSAGE		58.08		190.89
COMPETITIVE			36.82	
D.W.				
LOCAL	1.22			1.07
MESSAGE		2.57		1.43
COMPETITIVE			2.07	1.50

*The standard errors have been suppressed but are available on the computer printouts to be supplied.

CHART 3.2

LOCAL SERVICES

2.30 $$\ln\left(\frac{QL}{POP}\right) = A_o + A_1 \ln\left(\frac{PQL}{CPI}\right) + A_2 \ln\left(\frac{YD}{CPI.POP}\right) + AD_1 . D_{59} + AD_2 . D_{70}$$

MESSAGE TOLL SERVICES

2.31 $$\ln\left(\frac{QM}{POP}\right) = B_o + B_1 \ln\left(\frac{PQM}{CPI}\right) + B_2 \ln\left(\frac{YD}{CPI.POP}\right) + BD_1 . D_{59} + AD_2 . D_{70}$$

COMPETITIVE SERVICES

2.32 $$\ln\left(\frac{QT}{POP}\right) = C_o + (C_{oo} - C_o) D_{64} + (C_1 + (C_{11} - C_1) D_{64}) . \ln\left(\frac{PQT}{CPI}\right) + (C_2 + (C_{22} - C_2) D_{64}) \ln\left(\frac{YD}{CPI.POP}\right)$$

Variable definitions as in Chart 3.1.

TABLE 3.3

PARAMETER ESTIMATES OF THE REFORMULATED 1978-1979 IAER DEMAND MODEL

EQUATION BY EQUATION

LOCAL SERVICES

Parameter	Estimate	Standard Error
A_o	-4.590*	.162
A_1	-.837*	.186
A_2	.756*	.142
AD_1	.184*	.021
AD_2	.026	.024
D.W.	1.85	
R^2	.9954	
Log of Likelihood function	48.79	

MESSAGE TOLL SERVICES

Parameter	Estimate	Standard Error
B_o	-5.184*	.120
B_1	-1.394*	.095
B_2	.761*	.100
BD_1	.122*	.010
BD_2	.111*	.014
D.W.	2.78	
R^2	.9994	
Log of likelihood function	62.38	

COMPETITIVE SERVICES

Parameter	Estimate	Standard Error
C_o	-7.801*	.569
C_{oo}	-8.222*	.604
C_1	-1.536*	.458

* Significant at the 5% level.

TABLE 3.3. (continued)

COMPETITIVE SERVICES

Parameter	Estimate	Standard Error
C_{11}	-7.327*	.565
C_2	1.743*	.451
C_{22}	2.698*	.518
D.W.	1.48	
R^2	.9985	
Log of Likelihood Function	38.34	

SYSTEM

Parameter	Estimate	Standard Error
A_o	-4.668*	.141
A_1	-.781*	.162
A_2	.832*	.124
AD_1	.172*	.018
AD_2	.011	.019
B_o	-5.254*	.105
B_1	-1.360*	.083
B_2	.828*	.088
BD_1	.113*	.009
BD_2	.096*	.011
C_o	-7.879*	.442
C_{oo}	-8.466*	.426
C_1	-1.467*	.362
C_{11}	-6.887*	.429
C_2	1.807*	.351
C_{22}	2.859*	.360
Log of Likelihood Function	165.349	

Equation	R^2	D.W.
Local	.9952	1.717
Message	.9993	2.521
Competitive	.9984	1.411

periods of 1954 onwards and 1953 onwards produced large fluctuations in parameter estimates and increasingly important autoregressive error structures. The reasons for this instability is probably associated with the behaviour of the disposable income term, which fell in both nominal and real terms in 1954. Other proxies for permanent "income" are being researched.

Table 3.3 contains the parameter estimates for the reformulated demand model for the sample period 1955-1976. (The 1977 and 1978 extended data were surpressed so that the comparison with the 1978-1979 demand model would not be biased).

The important features of the reformulated demand model are:

(1) The absence of autoregressive error structures. Parameter estimates of first order serial correlation coefficients were insignificant. The Durbin-Watson statistics for the equations are quite good and any divergence from an "ideal" Durbin-Watson statistic appears to derive from the structural change present in each of the equations.

(2) The strong similarity of parameter estimates equation by equation versus the seemingly unrelated system.

(3) The larger price elasticity of local services. This increase in elasticity is consistent with IPA estimates (private communication with M. Fuss) and may well indicate that the local price is not the basis of marginal decisions. This feature is currently being researched by A. Jackson at the IAER and will be discussed more completely later in this Report.

(4) The shift of price elasticity in the competitive services equations. This shift suggests that WATS demand is quite dissimilar from the rest of competitive services and it is fortunate that data now exists to isolate it.

PART 4

In Parts 2 and 3 of this Report a three-input three-output cost model and a reformulated three service demand model were introduced. In this Part of the Report, we consider the simultaneous estimation of the demand and cost models.

Section 4.1 Background Discussion

Assuming that a profit maximization characterization of the Bell decision making process is germane for message toll and competitive services then there will be simultaneity between input and output choices. This suggests that more efficient demand and cost model parameter estimates could be obtained by simultaneously estimating the cost and demand models. As well, simultaneous estimation would minimize any simultaneity bias arising from estimating the demand system separately and using the parameters of the demand model as extraneous information in the cost model.

However, there are some drawbacks associated with such a large model.

In the first place, as stated, such a model would require the simultaneous estimation of 52 parameters of which 44 are directly estimated and 8 are obtained residually. Fortunately, it was possible to improve upon our full information maximum likelihood algorithm such that the size problem was overcome.

Secondly, the fact that 8 equations could be simultaneously estimated suggests that convergence problems arising from a "bumpy" likelihood function would be encountered. Such problems were encountered and sorted out to a larger extent.

Finally, if one of the equations is structurally dissimilar from the others, the estimation problems arising from this equation may carry over to the system as a whole. The demand for competitive services equation provides a good example. As specified, this equation involves a potential discrete jump in the demand elasticity in 1964. Should this jump arise then the fact that marginal revenue of competitive services is related to this elasticity by equation 2.26 suggests that the discrete jump in elasticity will affect the profit maximization condition. Given the continuity of most of the variables in the marginal cost equation for competitive services, it may well be difficult to get a good fit for this equation about the 1964 jump point. This problem in fact arises and it would appear that little can be done to overcome this problem given that WATS remains in competitive services. Fortunately, the necessary data now exists to strip WATS from competitive services and place it into message toll services where it more correctly belongs.

Section 4.2 Specification and Estimation of the Joint Demand and Cost Model

The model as specified contains equations 2.1, 2.2, 2.3, 2.5, 2.6, 2.30, 2.31, and 2.32. Marginal revenue is introduced into equations 2.5 and 2.6 according to equation 2.26. Thus the demand and cost equations are jointly linked by the price elasticities B_1, C_1, and C_{11}. As well, all equations are linked by the endogenous variables specified to be the outputs of the three services, QL, QM, and QT. Labour share, capital share and cost form three additional endogenous variables. Closing the model by specifying that the prices of message toll and competitive services be endogenous led to a very nasty likelihood function with nemerous local optima. It was determined that the majority of problems arose from the competitive services profit equation. However, when the system was closed by specifying the difference between marginal revenue and marginal cost (or zero) to be endogenous for both profit equations, global convergence was achieved. The parameter estimates of this model are presented in Table 4.1; summary statistics are presented in Table 4.2.

Section 4.3. Analysis of the Results

The equation by equation analysis of the model as well as the relatively small standard errors of the estimates suggests that the fit of the model is quite tight. The only really disturbing feature of the model is the residual plot of the competitive profit maximization equation. The discrete jump in the marginal revenue series in 1964 leads to a less than adequate fit of the equation in the early part of the sample. This result filters through the model and affects the concavity of the cost function for two of the first three years of the sample. As well, the profit maximizing second-order conditions are not met for competitive services, however, they are within 5% of being satisfied. Finally, the point estimate of the demand elasticity for the first part of the sample is quite close to the estimate from the demand system alone. The large movement occurs in the second half of the sample where the elasticity is twice that arising from the demand system alone.

The message toll profit equation fits well and the point estimate of the price elasticity is quite close to the separate demand system elasticity estimate. For most years the profit maximization second-order conditions are satisfied for this service.

TABLE 4.1

PARAMETER ESTIMATES OF THE JOINT COST AND DEMAND MODEL

Parameter	Estimate	Standard Error
CC_o	.039*	.006
C_w	.338*	.003
C_r	.475*	.003
C_v	.186*	.005
C_T	-.898*	.108
C_{ww}	.100*	.019
C_{wr}	-.105*	.013
C_{wv}	.006	.018
C_{wT}	-.348*	.036
C_{rr}	.214*	.019
C_{rv}	-.108*	.016
C_{rT}	.410*	.046
C_{vv}	.103*	.022
C_{vT}	-.062*	.031
C_{TT}	.399	1.170
C_{QL}	.807*	.060
C_{QM}	.141*	.006
C_{QT}	.050*	.002
C_{QLQL}	.806*	.344
C_{QMQL}	-.087*	.013
C_{QTQL}	-.040*	.009
C_{QLT}	-1.231	.626
C_{QMQM}	.039*	.005
C_{QMQT}	.012*	.003
C_{QMT}	.012	.010
C_{QTQT}	.019*	.003
C_{QTT}	.022*	.008

TABLE 4.1 (continued)

Parameter	Estimate	Standard Error
C_{wQL}	.031	.028
C_{wQM}	.043*	.007
C_{wQT}	-.014*	.004
C_{rQL}	-.081*	.035
C_{rQM}	-.071*	.009
C_{rQT}	.036*	.005
C_{vQL}	.050	.029
C_{vQM}	.028*	.007
C_{vQT}	-.022*	.005
A_o	-4.257*	.054
A_1	-1.090*	.061
A_2	.479*	.047
AD_1	.163*	.009
AD_2	.092*	.008
B_o	-4.821*	.063
B_1	-1.713*	.049
B_2	.475*	.054
BD_1	.119*	.007
BD_2	.118*	.008
C_o	-6.241*	.170
C_{oo}	-7.531*	.191
C_1	-3.012*	.122
C_{11}	7.003*	.289
C_2	.485*	.133
C_{22}	1.948*	.153

* Significant at the 5% level.

TABLE 4.2

EQUATION BY EQUATION SUMMARY STATISTICS

EQUATION	R^2	D-W	SSR
Cost Function 2.1	.9992	1.156	.006
Labour Share 2.2	.9810	.844	.001
Capital Share 2.3	.9807	1.402	.001
Message Profit 2.5	*	1.389	.001
Competitive Profit 2.6	*	.760	.0001
Local Demand 2.30	.9945	.769	.025
Message Demand 2.31	.9993	1.839	.006
Competitive Demand 2.32	.9970	.8237	.074

*Equation estimated in implicit form.

Finally, the local demand equation fits somewhat less well than in the separate demand system. The point estimate of the price elasticity now exceeds unity. As observed in previous demand studies at the IAER, the fit of the local equation seems to depend upon the other toll equation.

The marginal cost of local services is everywhere greater than the price. During the latter part of the sample it increases rapidly to a level of $2.06 compared to the price of $1.27.

Capital and labour are both estimated to be substitutes in production. Throughout the entire sample period the elasticity of substitution between capital and materials is negative suggesting that these two factors are complements.

The factor share equations fit quite well and the tracking of input demands through the derivative of the cost function is quite good. However, two points should be noted. First, the factor price elasticity of labour is lower than the previous years estimates and remains relatively constant throughout the sample. Secondly, the factor price elasticity of capital is quite small and close to -.07.

Finally, with respect to scale and scope, the measure of scale economies indicates minor decreasing returns to scale for the first part of the sample - switching over to minor increasing returns for the second part. This switch-over may well be induced by the fit of the competitive service profit equation. There is only minor evidence of cost complementarities for local and competitive services and none for other services suggesting, along with the low scale estimates, that no conclusions regarding economies of scope can be drawn.

Section 4.4 Concluding Comments

As the previous discussion suggests, we have not converged to the final cost and demand model. We do however feel that we have made significant progress in the estimation of an integrated demand, supply and factor share model of Bell. As well, the models of the IAER based on the old definition of competitive services must be set aside. Future research will concentrate upon a competitive service with WATS removed. The feasibility of these models has been established; however, further estimation problems are bound to arise.