SPECIFYING AND ESTIMATING MULTI-PRODUCT COST FUNCTIONS FOR A REGULATED TELEPHONE COMPANY

Bridger M. Mitchell

February 1978

P-6078

The Rand Paper Series

Papers are issued by The Rand Corporation as a service to its professional Staff. Their purpose is to facilitate the exchange of ideas among those who share the author's research interests; Papers are not reports prepared in fulfillment of Rand's contracts or grants. Views expressed in a Paper are the author's own, and are not necessarily shared by Rand or its research sponsors.

The Rand Corporation
Santa Monica, California 90406

Specifying and Estimating Multi-Product Cost Functions for a Regulated Telephone Company*

Bridger M. Mitchell

International Institute of Management
and
The Rand Corporation

Introduction

Melvyn Fuss and Leonard Waverman have given us a stimulating paper, reemphasizing the importance of closely examining the behavior of the multiple-product firm and focusing our attention on the central difficulties of analyzing common costs in a regulated market. Their analytic methods--particularly when developed in more extensive form--promise to be a welcome addition to the economists' toolkit in addressing public policy issues of rate structure, entry and competition, and the appropriate extent of monopoly supply. Their present paper, however, falls short of providing empirical results bearing on the policy questions that arise in regulation of the telecommunications sector.

I will briefly review Fuss and Waverman's methodology and comment on the appropriateness of their data as well as their modeling of regulatory constraints and of demand. I will then suggest how Fuss and Waverman's econometric methods might be combined with an alternative procedure for estimating joint cost functions, an approach that holds greater promise for empirically establishing the long-run parameters of the production technology in the telecommunications sector.

---

*This note is an elaboration of my discussion of the paper "Multi-product Multi-input Cost Functions for a Regulated Utility: The Case of Telecommunications in Canada" by Melvyn Fuss and Leonard Waverman, presented at the National Bureau of Economic Research Conference on Public Regulation, Arlington, Virginia, December 16, 1977. Preparation of these remarks has been supported by a fellowship from the German Marshall Fund and by National Science Foundation grant No. APR 77-16286 to The Rand Corporation.

SPECIFYING AND ESTIMATING MULTI-PRODUCT COST FUNCTIONS FOR A REGULATED TELEPHONE COMPANY

Bridger M. Mitchell

February 1978

P-6078

The Rand Paper Series

Papers are issued by The Rand Corporation as a service to its professional Staff. Their purpose is to facilitate the exchange of ideas among those who share the author's research interests; Papers are not reports prepared in fulfillment of Rand's contracts or grants. Views expressed in a Paper are the author's own, and are not necessarily shared by Rand or its research sponsors.

The Rand Corporation
Santa Monica, California 90406

Specifying and Estimating Multi-Product Cost Functions for a Regulated Telephone Company*

Bridger M. Mitchell

International Institute of Management
and
The Rand Corporation

Introduction

Melvyn Fuss and Leonard Waverman have given us a stimulating paper, reemphasizing the importance of closely examining the behavior of the multiple-product firm and focusing our attention on the central difficulties of analyzing common costs in a regulated market. Their analytic methods--particularly when developed in more extensive form--promise to be a welcome addition to the economists' toolkit in addressing public policy issues of rate structure, entry and competition, and the appropriate extent of monopoly supply. Their present paper, however, falls short of providing empirical results bearing on the policy questions that arise in regulation of the telecommunications sector.

I will briefly review Fuss and Waverman's methodology and comment on the appropriateness of their data as well as their modeling of regulatory constraints and of demand. I will then suggest how Fuss and Waverman's econometric methods might be combined with an alternative procedure for estimating joint cost functions, an approach that holds greater promise for empirically establishing the long-run parameters of the production technology in the telecommunications sector.

---

*This note is an elaboration of my discussion of the paper "Multi-product Multi-input Cost Functions for a Regulated Utility: The Case of Telecommunications in Canada" by Melvyn Fuss and Leonard Waverman, presented at the National Bureau of Economic Research Conference on Public Regulation, Arlington, Virginia, December 16, 1977. Preparation of these remarks has been supported by a fellowship from the German Marshall Fund and by National Science Foundation grant No. APR 77-16286 to The Rand Corporation.

The Model

The authors assume that three aggregate services (Y_i) are produced from three aggregated inputs (X_j) by a general multi-product transformation function with convex isoquants:

(1) $F(Y,X) = O \qquad Y = (Y_1, Y_2, Y_3), \quad X = (X_1, X_2, X_3).$

Provided that input prices (p) are exogenous, a cost-minimizing firm will have the dual cost function

(2) $C(Y,p) \qquad p = (p_1, p_2, p_3)$

which embodies all of the technical information contained in (1).

Fuss and Waverman particularize this model by specifying (2) to be a general quadratic function in the logarithms of total cost, output and price variables (the so-called trans-log cost function). They assume that the firm maximizes profits

(3) $\Pi = \Sigma q_i Y_i - C$

subject to a regulatory constraint to be specified. This behavior implies a particular structure for the cost shares

(4) $$\frac{p_j X_j}{C} = f_j(Y,p) \qquad j = 1,2,3$$

and the "revenue shares" of the outputs

(5) $$\frac{q_i Y_i}{C} = g_i(Y,p,\eta) \qquad \eta = (\eta_1, \eta_2, \eta_3), \quad i=1,2,3.$$

In their application of this model the authors simultaneously estimate the parameters of the 7 equations in (2), (4) and (5) by iterated three-stage least squares, assuming that technological change is Hicks-neutral and that per capita income and Y_1 (local telephone service) are exogenous variables. The demand elasticities, η_2 and η_3, for the endogenous outputs, Y_2 and Y_3, are estimated from independent demand equations.

The principal empirical findings are that the overall returns to scale elasticity is slightly less than unity, that incremental costs for Y_1 are increasing and for Y_2 and Y_3 are decreasing, and that all inputs are substitutes.

Data

The authors use annual time series data for Bell Canada for the period 1952-1975. Output is aggregated into three services: local (Y_1), toll (Y_2), and "competitive" services (Y_3). The last category includes private line, data,TWX, and wide-area telephone service (WATS) as well as directory advertising. For Y_2 and Y_3 constant-dollar quantity indices were available. and prices (q_2, q_3) were computed as implicit indices from the ratios of current revenues and the quantity indices. The output measure for local service (which is unexplained) could be either the number of main telephone stations or the quantity of local calls. Since flat-rate charges were in effect for most customers during this period, it would be inappropriate to use demand estimates based on an average price per call.

Inputs are similarly aggreagated into 3 broad categories--materials, labor, and capital--by constructing annual price indices for each category.

The time-series nature of the data employed by the authors pose a fundamental question for the interpretation of their results: are year-to-year changes in total cost, factor cost shares and output prices a reliable basis for estimating the long-run multi-product production function? Unfortunately, annual data are dominated by short-run behavior and often reflect disequilibrium conditions. This extremely capital-intensive industry is characterized by lumpy and large-scale investment projects requiring years for system-wide installation. Capacity utilization ("fill") shows significant annual variation. Moreover, the structure of the firm's output prices is not readily adjusted to reflect year-to-year changes in both demand conditions and relative prices of inputs. Finally, the precision of the parameter estimates is restricted by the limited variation

in prices, factor shares and output proportions observed in time-series data. At best, then, the data used by the authors could permit them to estimate the local properties of short-run cost and production functions.

Regulatory Constraint

The impact of regulation on the multi-product firm is a challenging topic, one worthy of extended investigation. Although the present paper represents a start in this direction, it does not reach the goal of analyzing the effect of regulation on a utility's actual behavior.

To formally introduce regulation into a model of a profit-maximizing multiproduct firm, the authors take two approaches. The first, used in their empirical work, is to assume that regulation constrains the price of one output (local service) and leaves the firm free to set the levels of the remaining prices. Fuss and Waverman choose local service as the exogenous output because their demand equation obtains an inelastic price coefficient, and the model cannot function with negative marginal revenue. The authors' alternative approach, which they develop theoretically for the trans-log cost function, is to assume that the firm is subject to classic rate-of-return regulation on total invested capital.

The difficulty, of course, is that regulators exert, or attempt to exert, control at many points. Indeed, the accounting procedures for separating common costs between services are intended to influence the rate levels of several services, and it is possible that such price regulation would force a regulated monopoly to operate at inelastic levels of demand in all markets. However, in an aggregative model one hesitates to use up more than one degree of freedom to specify the regulatory constraint and there is no readily-available theory of regulators' preferences to specify the degree of price control exerted in each market. It would, therefore, be interesting to have the results of the authors' second approach--for a profit-maximizing firm constrained only by rate-of-return

regulation--to examine how closely such a firm's output prices resemble those observed in the data.

Finally, the authors note that rate of return regulation was imposed on Bell Canada in the middle of the sample period. Did this change in the firm's regulatory environment influence its costs and product behavior?

Demand

Fuss and Waverman estimate a log-linear equation for the quantity of each of the three aggregate telecommunication services as a function of each service's own price and of real income per capita. The authors' cursory attention to the demand side of the market--they suggest that their equations be regarded as first-order approximations to arbitrary demand functions--stands in sharp contrast to their systematic development of the implications of joint products on the supply side. In principle, the demands for local, toll and "competitive" services are interdependent and must be represented in the form of a joint demand function

(6) $D(Y,p) = 0$.

Several types of interdependencies are likely to be important for the particular output aggregates used by the authors. First, the price of local service is both the cost to the customer of local calling and the price of access to obtain toll services, since he must first have a local telephone in order to place long-distance calls. The demand for toll services will, therefore, be a function of both local and toll service prices, especially for high-volume toll users who must purchase additional local lines in order to obtain access to the toll network. Second, some of the competitive services, particularly wide-area telephone service (WATS), are close substitutes for message-toll service for high-volume users. The demands for Y_2 and Y_3 should, therefore, each be functions of both q_2 and q_3. Finally, telephone service has long been recognized as a case in which important externalities exist in the demand

functions of individual consumers. In the demands for both local service and message toll service the number of persons connected to the telephone network positively affects the demand for access as well as the number of calls at given prices. This externality, when incorporated into the firm's profit-maximizing calculus, can result in positive marginal revenues from supplying local service even when the demand function is apparently inelastic.

A satisfactory empirical investigation of the system of demand equations relevant to the Fuss and Waverman production structure will itself be a challenging undertaking. Over the period 1952 to 1975 important structural changes have occurred in telephone services. The introduction of direct distance dialing and of off-peak discount rates for toll calls has had a pronounced effect in stimulating message-toll traffic. Similarly, the availability of WATS and discount rates for bulk toll service and the recent emergence of competitive carriers for specialized inter-city services has affected the conventional message toll market as well as the market for other telecommunication services. Realistic estimates of the demand structure will need to incorporate at least the basic nature of these trends.

Finally, one can well sympathize with the authors for avoiding the additional difficulties posed by the simultaneity of demand and cost functions in a complete representation of their model. Nevertheless, it is clear that if the multi-product firm's price policy is endogenous in its production decisions, then one may not without further investigation assume that prices are predetermined in using market data to estimate the system of demand equations that it faces.

An Alternative Approach

As an alternative to the direct econometric estimation of production or cost functions for the multi-product firm, one may incorporate the major characteristics of the firm's joint production technology into a process model. In the telephone

industry such an approach has been developed by Littlechild (1970). A process model incorporates multiple outputs Y_i and a technology consisting of items of equipment K_j with maximal capacities $\bar{K}_j$. In such a model particular pieces of equipment are in common use for multiple outputs. For example, K_1, the local loop and switch, provides capacity that is shared between local and toll services. The capacity constraints are that usage summed over the set of outputs using each item of equipment not exceed the available capacity

$$(7) \sum_{i \varepsilon B_j} Y_i \leq \bar{K}_j .$$

Each item of equipment is associated with a long-run cost function that, in general, may incorporate economies of scale and factor substitution

$$(8)\ c_j(K_j, p).$$

When a particular set of regulatory constraints is imposed, the process model is optimized for a specified objective function. For example, the firm may be assumed to maximize profits

$$(9)\ \Pi = \sum_i q_i Y_i - \sum_j c_j(K_j, p).$$

As outputs, the process model yields the quantities and prices of market services, levels of inputs, and the shadow prices of each service. An important feature of the process-model approach is that the shadow prices may be interpreted as the long-run marginal costs of expanding the output of each service.

It is possible to combine the econometric and the process approaches. Beginning with the process model, one may vary the input prices orthogonally over a wide range to generate minimum-cost solutions for joint production. (The model may also be used to introduce new technologies, different regulatory constraints or the entry of competitors). The prices and outputs of these solutions constitute pseudodata that embody the firm's

long-run responses to differing market conditions. One can then use these pseudodata to econometrically estimate a smooth multiple-output cost or production function such as the translog function. Such a function will summarize the production technology into a small number of parameters representing the degree of scale economies, the nature of input substitution, and character of expansion paths. This alternative approach of combining process information with econometric specifications avoids many of the problems inherent in time-series data, including multi-collinearity, limited sample variation in key variables, and the presence of disequilibrium behavior.

Griffin's (1977) initial study of multi-output production in the electric power industry suggests that the psuedo-data approach can elucidate policy questions that depend on the empirical measurement of long-run parameters. Although Fuss and Waverman's time-series analysis does not yield reliable information on these questions, the application of their methodology in conjunction with a process model is a promising line of future inquiry.

References

Griffin, James M. "Long-run Production Modeling with Pseudo Data: Electric Power Generation", Bell Journal of Economics,Vol.8, No.1, Spring 1977, pp.112-127.

Littlechild, S.C. "Peak-load Pricing of Telephone Calls", Bell Journal of Economics and Management Science, Vol. 1, No. 2, Autumn 1970, pp.191-210.