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Project Summary

Economic Modelling of Water Supply: An Econometric Analysis of the Multiproduct Firm

Hak Youn Kim

Research was conducted to develop a comprehensive economic model that could use the neoclassical theory of the multiproduct firm to analyze the production structure of water supply. The project attempts to meet the need for in-depth analysis of the cost and economic structure of water supply.

The cost structure of the water supply industry was estimated using the recently refined translog function. Issues addressed included restrictive specifications for water supply technology, input demand function for water supply, scale economies, marginal costs and output supply, and pricing of water and the presence of cross subsidization among residential and nonresidential users.

Findings of this research represents the first attempt to apply the translog production function in the water supply area. No comprehensive analysis has been conducted before using the econometric methodology adopted in this study.

This Project Summary was developed by EPA's Water Engineering Research Laboratory, Cincinnati, OH, to announce key findings of the research project that is fully documented in a separate report of the same title (see Project Report ordering information at back).

Nature of the Problem

The world's present water supply situation is substantially different from that of the past. Scarcity of high-quality water is evident in many locations in the United States and in other countries. Per capita consumption of water has continued to rise with increasing affluence and urbanization, but many existing water sources have become limited in availability and degraded in quality. Increasing energy costs coupled with inflation and high interest rates have raised the costs of providing water. In addition, more stringent environmental regulations (e.g., the Safe Drinking Water Act of 1974) have the potential for increasing water rates.

In recognition of growing water supply problems, the United Nations has designated the 1980's as the International Drinking Water Supply and Sanitation Decade. The primary goal is to provide the world with safe water and sanitary disposal of human wastes. In this period of rising costs and impending regulatory changes, the costs of water supply and the factors affecting these costs have taken on new importance.

The conventional solution to water supply problems has been to augment supplies by expanding the system and acquiring the resources as needed to meet the full demand of customers. But the problems of supplying water of acceptable quality are no longer simple. Issues related to substitutabilities among water supply inputs have become important for the policy maker, who must understand implications of increasingly scarce resources. Knowledge of scale economies and their limitations have implications for "regionalization" policies. Also, utility

commissions have begun to devote more attention to rate structure reform. The issue of public versus private water providers is becoming more important as communities search for ways to improve management and operation of water supply.

As the emphasis on water supply issues grows, so does the need for an in-depth analysis of the cost and economic structure of water supply. Previous research efforts to meet this need have been limited in scope and applicability. The present research seeks to fill that gap.

Purpose of the Research

The object of this research is to develop a comprehensive economic model that could use neoclassical theory of the multiproduct firm to analyze the production structure of water supply. In this study, the water supply utility is viewed as a regulated multiproduct firm offering multiple services to various classes of consumers with spatial and temporal variations. Particular attention is directed to the production characteristics of the multiproduct firm. This research project assumes that many issues in water supply can be resolved by applying some basic neoclassical multiproduct production theory. Specifications for the water supply technology used in this research were derived in a manner that is entirely different from the neoclassical microeconomic theory.

The following issues are addressed in the development of the model: (1) restrictions posed by existing specifications for water supply technology in view of the neoclassical theory of production; (2) input substitution and use in the production process; (3) scale economies; (4) marginal costs and the transformation function of water supply; and (5) second best pricing and the presence of cross-subsidization among customer classes because of inappropriate pricing structures.

Though this research is primarily concerned with the analysis of water supply problems, it encompasses many practical problems and issues faced by other utilities and regulated industries. Thus the analytical and empirical methods adopted in this research should provide a useful framework to study not only the water supply industry but also the multiproduct firm in general. Econometric analysis of the general multiproduct firm is far from complete in view of the fact that most of the work in this area has been only preliminary and suggestive without regard to practicality and policy relevance.

Methodology of the Research

The approach of this research is to estimate the cost structure of the water supply industry using the recently refined translog function. The translog function can deal with multiple inputs and outputs, variable elasticities of substitution among inputs, variables elasticities of transformation among outputs, and variable economies of scale. The theory of duality is explicitly explored in the estimate of the translog cost function.

The water supply firm produces multiple outputs for different customer classes such as residential and nonresidential users. Capital, labor, and energy are considered as the major inputs into the production process for the delivery of water and to meet customer demands. Interaction among outputs and inputs is taken into account in the estimate, and various hypotheses of the production structure are tested. The data used represent a cross section of water utilities in the United States for the year 1973.

An unusual feature of the methodology used here is the direct incorporation of the firm's operating characteristics into the specifications for the technology. Operating characteristics include capacity utilization and service distance, which are considered important for production and delivery of water supply. With the generalized cost function (which includes operating characteristics in addition to conventional arguments of ouputs and input prices), it is possible to obtain insights into the quantitative relationship between costs and operating conditions.

Estimates of the translog cost function by ordinary least squares would be imprecise because of possible multi colinearity resulting from a large number of regressors interacting with one another. Thus our estimates use the iterative Zellner efficient method, which jointly estimates the translog cost function and the input demand functions derived as the first order conditions of cost minimization. The iterative Zellner efficient method is asymptotically equivalent to the maximum likelihood method.

Major Findings of the Research

Parameter Estimates and Tests of Restrictive Specifications for Technology

Estimates of water supply costs presume nonhomotheticity that prescribed differences exist among outputs (residential and nonresidential water supply), input prices, and operating variables (capacity utilization and service distance). The translog multiproduct cost function is an adequate description of the technology of water supply. The tests of homogeneity of outputs, input-output separability, nonjointness, and a Cobb-Douglas form produce results that are significantly different from the unconstrained translog cost model. This result suggests that existing specifications placing arbitrary restrictions on the translog multiproduct cost function are inappropriate. In addition, our findings reject the hypothesis that the operating variables should be excluded from the model. Attempts to analyze water supply costs without considering the operating variables would lead to false conclusions about the structure of water supply.

Input Demand Function for Water Supply

No previous studies have been performed to estimate the input demand function for water supply. Capital is a substitute for labor and energy. Substitution between energy and labor is limited to a great extent. Substitution between capital and energy is consistent with the findings of studies in other areas. Energy is an input that requires intensive use in the production process in response to changes in the demand for water and capacity utilization. Furthermore, capacity utilization and service distance have significant effects on input requirements. Thus the inability to account for these variables would lead to a serious problem in estimating of input requirements for water supply.

Scale Economies

Water utilities experience substantial economies of scale for both residential and nonresidential water supply. The water supply industry is experiencing marked economies associated with the treatment of water, but it suffers from diseconomies with increasing size of distribution network. The economies in treatment override the diseconomies in distribution, however. Furthermore, scale economies are mainly determined by nonresidential water users as opposed to residential users.

Marginal Costs and Output Supply

Marginal costs of residential and nonresidential water supply are much

lower than the actual prices charged. Marginal costs are quite sensitive to changes in outputs, input prices, and operating variables. Marginal costs are estimated from the transformation function of water supply. The latter is convex and illustrates decreasing real opportunity costs of residential and nonresidential water supply. This observation implies an advantage to specializing either in residential or nonresidential water supply.

Pricing of Water and Cross-Subsidization Among Customer Classes

The economies of scale experienced by water utilities suggest that marginal cost pricing is not feasible. The second best pricing rule has been proposed as an alternative scheme through which prices can be calculated for residential and nonresidential water supply. Surprisingly, the existing price structure is close to the second best pricing optimum. The fact that marginal costs are less than the actual prices indicates that real costs of water supply are much lower than expected. In addition, this study finds no evidence of cross-subsidization among residential and nonresidential users.

Empirical findings in this research represent first attempts in the water supply area. No comprehensive analysis has been conducted in the past using the econometric methodology adopted in this research. However, before sweeping or definite conclusions can be drawn from these findings, it is important to verify them using different data. This step is necessary because of the limitations imposed by the data currently available. Nevertheless, the methodology used in this research should provide fruitful lines of inquiry into the various issues associated with water supply.

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Hak Youn Kim is now with Western Kentucky University, Bowling Green, KY.
***Robert M. Clark** is the EPA Project Officer (see below).*
The complete report, entitled "Economic Modelling of Water Supply: An Econometric Analysis of the Multiproduct Firm," (Order No. PB 85-176 899/AS; Cost: $20.50, subject to change) will be available only from:
National Technical Information Service
5285 Port Royal Road
Springfield, VA 22161
Telephone: 703-487-4650
The EPA Project Officer can be contacted at:
Water Engineering Research Laboratory
U.S. Environmental Protection Agency
Cincinnati, OH 45268

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