

Cost Functions and Nonlinear Prices: Estimating A Technology with
Quality-Differentiated Inputs

Charles D. Kolstad and Michelle H.L. Turnovsky

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DATA APPENDIX
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All the generating unit data are constructed for the first full year of unit operation. This is assumed to be one year after the published date at which the unit enters commercial operation since that published date may correspond to an incomplete year. The first full year of operation is referred to "the first year of operation plus one." Data used for estimating the cost function are given in Tables A-I through A-IV.

A. Quantity of Capital

The basic source at the unit level is "Construction Costs of U.S. Steam Electric Plants 1970-1985," Utility Data Institute, Inc. The costs have to be adjusted because they are calculated as the sum of the yearly capital expenditures during construction. A method proposed by Joskow and Rose (1985) permits us to correct for the effect of changes in prices and interest rates during the construction period (assumed to be five years):

$$\text{Total costs in 1st year of operation} = \frac{\text{nominal costs}}{j_{t,1}^{5} S_t \left[\frac{k_{i,1}^t (1\%p(i))}{k_{j,t}^5 (1\%r(j))} \right]} \quad (A-1)$$

where S_t is the share of actual construction expenses in year t with $t = 6$ being the year of first operation (source: Personal

Communication, Nancy Rose, 1987): $S_1 = .10$, $S_2 = .32$, $S_3 = .39$, $S_4 = .16$, and $S_5 = .03$; $p(i)$ is the percentage change in input prices in year i (from the Handy-Whitman Construction Cost Index for all Steam Plant by regions, taken from the Moody Utility Manual); $r(j)$ is the average allowance for funds used during construction in year j (from Financial Statistics of Selected Electric Utilities, Energy Information Administration, Table 16: Electric Utility Plant Construction Work in Progress and Table 17: Net Income and Allowance for Funds Used During Construction). Costs so calculated are then adjusted to 1976 using the regional Handy-Whitman construction cost index to obtain the quantity of capital.

B. Price of Capital Services

The price of capital services is calculated following the Christensen and Jorgenson (1969) approach for the first year of operation plus one:

$$P_i = \frac{a + uz + k}{1 + u} [q_{i,t} r + q_{i,t} d + (q_{i,t} + q_{i,t+1})] + q_{i,T} \quad (A-2)$$

where u is the Effective Corporate Tax rate from the "U.S. Long Term Review," Data Resources, Inc; z is the present value of \$1 of depreciation for tax purposes,

$$z = \frac{1}{rt} \left[1 - \left(\frac{1}{1+r} \right)^t \right], \quad (A-3)$$

and t is the life of the utility for tax purposes which is assumed to be 28 years (based on estimates in Christensen et al., 1980). Note that

the price of capital services is in nominal terms and will escalate with the price level.

k is the investment tax credit rate. Two series are available in the DRI "U.S. Long Term Review." One is for equipment and the other for public utilities structures. As the power plant cost data published by the Utility Data Institute are broken down into land, structures and equipment, it is possible to construct, for each unit, a weighted average of the structures series and equipment series using the ratio of equipment over total costs and of structures over total costs as weights.

q is the price of capital measured with the Handy Whitman index and broken down into six main regions (table entitled: Costs Trends of Electric Light and Power Construction from Moody's Nation Wide Survey of Public Utility Progress). The July 1st observation for the relevant region is chosen with July 1, 1976, as the base year.

r is the rate of return. It is calculated as a weighted average of the rate of return on common equity, r_e , and the rate of return on long term debt, r_d . The weights are constructed with the help of the capitalization ratios presented in the "Statistics of Privately Owned Electric Utilities in the United States (DOE/EIA-0044, Table 37: Selected Financial Indicators). The rate of return of common equity, r_e , is also available in the above table. r_d is the coupon rate of the long term bonds issued in the first year of operation plus one. It is taken from the Moody's Public Utility Manual. Finally, in the case of a publicly owned utility, the rate of return is assumed to be the 30-year Treasury bonds rate. (Note that these financial data are only available by utility, they are not specific to the generating unit.)

d is the economic rate of depreciation. Following Christensen et al. (1980), it was chosen using the 1.5 declining balance method and using their engineering estimates of 33 years for the average service life; hence $d = 1.5/33 = .045$.

T is the effective rate of property taxation in the relevant county. The sources are the 1977 and the 1982 Census of Government, Volume II, entitled, Taxable Property Values and Assessment Sales Price Ratios. The year closest to the first year of operation plus one was chosen and the rates were adjusted in order to apply to land and structures only. (Note that the data were not very specific but it is likely that the error introduced by totally ignoring T would be greater.)

C. Quantity of Output

The quantity of output is constructed as quantity of coal purchased divided by the heat rate (thermal efficiency); this assumes that the quantity of coal purchased is approximately equal to the quantity of coal used. The reason for using this measure of output is that some units are multi-fuel. The quantity of coal is reported on FERC Form 423 and is also available in "Cost and Quality of Fuels for Electric Utility Plants (various years). The heat rate for each plant is published in Thermal-Electric Plant Construction and Annual Production Expenses (DOE/EIA-0323).

D. Sulfur Ash and Fuel in the Nonlinear Price Functions

All electric utility transactions for coal are reported in FERC Form 423. Quality characteristics for these transactions include price, thermal content and sulfur and ash content in percent by weight. These

data were used to estimate the nonlinear price functions, converting sulfur into pounds per million Btu, ash into pounds per 100,000 Btu and price in \$ per million Btu in order to estimate the price functions; the quantity data for fuel are converted into million Btu using the reported Btu per pound conversion factor. All transactions in a state during a year were used to estimate the individual nonlinear price functions. In a few cases, neighboring small states were aggregated to increase sample size. Table A-III contains the results of the estimation of the nonlinear price function for each generating unit. Monotonicity and convexity of the price function have been imposed, which is the reason many coefficients are zero.

E. Total Costs

Total costs for the cost function are calculated for the first year of operation plus one. They are constructed as the sum of the value of capital services calculated above and the value of coal for the first year of operation plus one. The value of coal is obtained by multiplying price per short ton by quantity in short tons, with the data from FERC Form 423, discussed above.

F. Instruments

Six instruments were used in the cost function estimation, all calculated for the first full year of operation as described above. The values of the instruments are given in Table A-IV.

Utility-level fuel consumption (in thermal units) is taken from the U.S. Department of Energy's "Cost and Quality of Fuels for Electric Utility Plants." Utility generation data (in KWh) was taken from the U.S. Department of Energy's "Statistics of Publicly Owned Electric

Utilities in the United States," and "Statistics of Privately Owned Electric Utilities in the United States." Total state coal consumption and state electricity consumption is taken from the U.S. Department of Energy's "State Energy Data Report." Energy demand growth for year t is $[\text{SED}(t+1) - \text{SED}(t)]/\text{SED}(t)$ where $\text{SED}(t)$ is state electricity consumption in year t . The deflated weekly wage is the state average weekly wage in manufacturing industry (from the Bureau of Labor Statistics, "Employment and Earnings") deflated to 1982 dollars using the GDP implicit price deflator.

REFERENCES (Appendix)

- Christensen, Laurits and Dale Jorgenson, "The Measurement of U.S. Real Capital Input, 1929-1967," Review of Income and Wealth, Series 15, No. 4, pp. 293-320 (1969).
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- Joskow, Paul and Nancy Rose, "The Effects of Technological Change, Experience, and Environmental Regulation on the Construction Cost of Coal-Burning Generating Units," Rand J. Econ., 16: 1-27 (1985).