AN AD-HOC MODEL OF NUCLEAR POWER COSTS

by
GERASIMOS T. SOLDATOS
Dept. of Economics. Clark University

1. INTRODUCTION

It is well known that nuclear power is not a viable alternative to fossil-based electricity production because of its economic disadvantages. Nuclear advocates assert that nuclear power costs are biased upward because as the technology increases on the learning curve and as plant engineering and construction emerges from the relatively inefficient shakedown stage, there will gradually be improvement. A number of studies, however, by Komanoff (1981), Mooz (1979), Shakow (1980) and others have refuted these contentions by offering via regression estimates, evidence that cost escalation will continue as long as performance and capital costs are influenced adversely by such variables as plant size, age of plant, and reactor technology. These studies ignore the fact that the technical and regulatory environment changes significantly from year to year and that the explanatory variâtes used to specify nuclear cost and performance are subject to multicollinearity. Recognition of this problem by Hohenemser, Fowler and Goble (1978), and Hohenemser and Goble (1979) has led to methods which are too cumbersome to use and they lack any underlying statistical model. Consequently, not only objective tests for hypotheses can not be formulated but in addition, the empirical evidence offered is basically the same.

The present paper is a report of a research on these issues through Monte Carlo Studies of a linear model of nuclear costs that takes into account (i) the instability of the relations between (a) nuclear cost and performance and (b) nuclear cost and plant characteristics, (ii) statistical rigor, and (iii) that escalating costs depend on the perceived as well as actual characteristics of plants. In this manner, we can obtain some reliable evidence on the determinants of nuclear power costs and performance. The conclusions drawn from this study will then be contrasted to a similar work of Shakow and Goble (1982).

2. THE MODEL AND THE METHODOLOGY OF THE EXPERIMENT

The basic equation used is the following linear function

$$\begin{aligned} C = {} & f\,(S_1, b_{1;}\ b_2, b_3) + f\,(S_2, e_{1;}\ e_2, e_3) \\ & + f\,(A, h_1, h_2, h_3) + f(V, m_1, m_2, m_3) \\ & + n_1\,D + n_2\,P + \qquad n_3 \end{aligned} \qquad \text{(I)}$$

where f(F, aj, at, ai) = (aj/2) TANH ((F-aj) / ai)), C denotes nuclear capacity factors, Si small size plants, S_2 large size plants, A isage of plant, V is the date of initial operation, D is single duplicate plants and P is public versus investor ownership. That is, nuclear costs depent on nuclear plant capacity factors which are in turn associated with objective plant characteristics. Nevertheless, factors such as the cost of borrowing to finance nuclear projects and lead times in the construction of nuclear plants are expected to be a measure of nuclear generation costs as well. In this case, our model should involve two more equations describing these variables as a function of the objective factors. Such relations, of course, would have the general linear form of equation [1]. Experimenting with Monte Carlo Studies for each one of these equations, we can the obtain a three-column data matrix as our dependent variable set to test the null hypotheses of equality of effect among technological characteristics perceived in terms of gross partitioned sets associated with variables such as size and facility duplication.

More precisely, given the numerical values assigned to the coefficients, the selected values of the explanatory variables and the chosen values of the random terms, (which are assumed to be normally distributed with zero mean and given covariances), we solve the equations of the model and obtain the generated value of the endogenous variables measuring nuclear power cost and performance. For each randomly drawn set of values of the random terms, a new generated value of the endogenous variables is obtained. With this procedure we form a sample of 25 generated observations for each of the three endogenous variables. This sample, together with the selected values of the explanatory variables are used to estimate the coefficients via an iterative search procedure that minimizes the residual sum of squares over the data base. The sample of the generated values of the endogenous variables is also used to perform multivariate analysis of "variance to test hypotheses concerning the effects of qualitative variables on a set of mutually correlated outcomes.

3. PARAMETER ESTIMATES AND HYPOTHESES TESTING

The parameter estimates are given in Table 1 while the results of F tests in the multivariate analysis of variance are summarized in Table 2. Table 1 is the outcome of numerous trials and shows that performance, as measured by capacity factors, cost of borrowing and lead times, is poorer for large plants and small age of plants. Public utilities plants show poorer performance, too. Moreover, plants of earlier vintage perform better even after allowing for their age and size.

Table 2 shows that reactor size is a significant factor affecting the extension of lead times for facilities. Size also appears to be associated with higher relative cost of borrowing. Vintage raises the level of perceived risk and duplicate plants within a project are less subject to uncertainty than single plants.

Similar results have been obtained by Shakow and Goble (1982) but now there exists some uncertainty as far as the conclusiveness of the hypotheses testing is concerned, and also, some evidence regarding the effect of objective plant characteristics on other than capacity factors measures of performance, i.e. cost of borrowing and lead times. Nevertheless, we do not recommend the use of these findings as a basis for quantitative inferences because they are the outcome of simulations rather than real data and the functional form of the model suggests a misleading degree of stability in the relationships.

Table 1

Parameter Estimates*

Esimates when the endogenous variable is Parameter–X^2 statistic	Cost of Borrowing	Capacity Factors	Lead Times
b_1	–2.08 (2.00)	–1.19 (1.07)	0.03 (0.12)
b_2	127.32) (84.19)	584.20 (116.28)	27.41 (10.02)
b_3	9.54 (4.40)	31.50 (12.85)	11.00) (6.13)
e_1	–3.30 (1.12)	–4.00 (2.54)	–2.19) (1.86)
e_2	60.20 (15.55)	948.30 (471.12)	71.96 (8.05)
e_3	14.71 2.25)	29.80 (1.48)	8.00 (0.09)
h_1	3.00 (1.79)	7.98 (2.31)	2.39 (1.62)
h_2	1.15 (0.44)	4.70 (0.09)	2.64 (1.08)
h_3	0.41 (0.01)	1.11 (0.52)	0.24 (0.00)
m_1	–4.13 (2.20)	–5.16 (3.02)	–3.98 (1.67)
m_2	4.48 (0.98)	5.00 (0.17)	3.74 (0.00)
m_3	0.78 (0.32)	1.73 (0.19)	1.00 (0.26)
n_1	3.16 (1.54)	4.32 (3.58)	5.85 (4.32)
n_2	0.88 (0.29)	1.01) (0.92)	0.00 (0.00)
n_3	6.07 (2.10)	5.30 (5.14)	8.17 (5.00)
x^2	176.00	213.29	148.61

* Standard errors in parenthesis

Table 2
Multivariate Analysis of Variance

	F statistic value	Significant 5 %	Significant 1 %
S	26.35	+	–
V	17.98	+	+
D	5.20	+	–

4. CONCLUDING COMMENTS

The report concludes with an evaluation of the qualitative results in the light of real world evidence from the U.S. A simple inspection of Table 3 shows that our propositions concerning the impact of objective plant characteristics on performance (average capacity factor), are consistent with the data. In this respect, we support previously published conclusions. But these conclusions should be reexamined to include other factors measuring performance such as interest rates (cost of borrowing) and lead times.

The argument for larger nuclear units simply restates the economic postulate that more, or the potential for more, is preferable to less. The postulate is no longer accepted. The translation into the nuclear power economics of the Bauhaus architectural principle that «less is more» has paved the way of the future of the nuclear plants. And insofar as the survival of the biosphere and safety are concerned, smaller reactors seem to be preferable.

Table 3

Capacity Factor and Plant Characteristics*

F	Average C : 1968 – 78
Average C	61.2
Deviation about average	±15.9
S	
400 – 599 MW	70
600 – 799 MW	62
800+ MW	56
D	
First unit	58
Second unit	62
A	
400–599 MW	
Year 1	57
Year 2	65
Year 3	70
Year 4	75
Year 5	78
Year 6 – 7	72
Year 8 – 11	77
600 – 899 MW	
Year 1 – 2	55
Year 3 – 4	62
Year 5 – 6	65
Year 7	69
800+ MW	
Year 1	55
Year 2	53
Year 3	54
Year 4	61
Year 5	61
Year 6 – 7	63

* Source : Hohenemser and Goble (1979). The sample includes 58 reactors. MW denotes Megawatts.

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