Technical Note
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Comments on Price/ Performance Patterns of U.S. Computer Systems

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Several errors are noted in the formulation of econometric models describing computer price/performance patterns. An alternative model is presented which shows the effects of technological advances and computer size on price reduction.

Key Words and Phrases: price/performance, U.S. computer market, econometric modeling
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In examining the econometric models developed in [1] to study the relationships between computer system price and hardware performance, several errors were noted. The model which is purported to provide the most consistent results is

$$\text{COST} = (B_0 + B_3 D_1 + \cdots + B_n D_n) * (\text{MEMORY}^{B_1} + \text{DASD}^{B_2}) \quad (1)$$

where[1]

- COST reflects system price;
- $D_1, \ldots, D_{n-1}$ are dummy variables representing year of system introduction;
- D_n is a dummy variable discriminating between small business computers and general purpose computers;
- MEMORY is the amount of main memory;
- DASD is the number of megabytes of on-line direct access storage.

An obvious error in the formulation itself is the coefficient on D_n, which should read B_{n+2}.

The major errors in the regression procedure occur when an attempt is made to construct the equivalent linear regression model of Eq. (1). It is immediately apparent by the additive form of the equation and the presence of 0–1 dummy variables that it is impossible to construct a log-linear regression equation from Eq. (1). The equation that the authors claim is equivalent is

$$\log\text{COST} = B_0 + B_1\log\text{MEMORY} + B_2\log\text{DASD} + B_3 D_1 + \cdots + B_n D_n. \quad (2)$$

This is actually equivalent to the multiplicative model

$$\text{COST} = e^{B_0}\,\text{MEMORY}^{B_1}\,\text{DASD}^{B_2}\,e^{D_1B_3}\cdots e^{D_nB_n} \quad (3)$$

which bears little resemblance to Eq. (1).

The model which we propose as an alternative formulation is

$$\text{COST} = B_0(\text{MEMORY} + \text{DASD})^{B_1}\,D_1^{B_2}\cdots D_n^{B_{n+1}} \quad (4)$$

We have incorporated four basic changes in the original model (2). The first is the minor correction of the coefficient of D_n to B_{n+1}. The second redefines the dummy variables to take on the value of 1 when false and e when true. The third is to take the logs of the dummies and also of the constant in the log-linear model. The fourth change concerns the addition of MEMORY and DASD. This must be done so that small systems that have no disk or drum storage capacity can be included in the model. It is now possible to solve the log-linear form of the model, which is

$$\log\text{COST} = \log B_0 + B_1\log(\text{MEMORY} + \text{DASD}) + B_2\log D_1 + \cdots + B_{n+1}D_n \quad (5)$$

The observations listed in Exhibits 1 and 2 of [1] also are employed as the data for our formulation. In the log-linear form, we find that

$$\begin{aligned}\log\text{COST} = {} & 3.017 + 0.6308\log(\text{MEMORY} + \text{DASD}) \\ & (14.63)\quad (21.03) \\ & -0.3262\log D_1 - 0.5186\log D_2 - 0.7447\log D_3 \\ & (-2.789)\quad (-5.045)\quad (-7.047) \\ & -0.1971\log D_4 - 1.089\log D_5. \\ & (-0.4510)\quad (-11.19)\end{aligned}$$

All t-statistics (in parentheses) are significant at the 99 percent confidence level except for B_4, the coefficient of the dummy variable signaling a 1978 introduction, which

Table I. Further Parameter Description.

Parameter	Units/Description
COST	$1000 increments
MEMORY	K-bytes
DASD	Megabytes
D_1	1 if 1972–73 introduction 0 otherwise
D_2	1 if 1974–75 introduction 0 otherwise
D_3	1 if 1976–77 introduction 0 otherwise
D_4	1 if 1978 introduction 0 otherwise
D_5	1 if small business computer 0 if general purpose computer

[1] See Table I.

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had only one observation. The value of the R^2 for this sample of 167 observations is 0.93. This is approximately equal to the R^2 value of the original (but incorrect) formulation (2).

When we derive the coefficients for Eq. (4), we find the relationship

$$COST = 20.43(MEMORY + DASD)^{0.6308} D_1^{-0.3262} D_2^{-0.5186} * D_3^{-0.7447} D_4^{-0.1971} D_5^{-1.089}$$

is the best unbiased estimate of a price/performance model of computer systems that can be solved in its log-linear form. This model clearly shows the effects of technological advances on price reduction, and also reflects the difference in price of large general purpose systems and small business computers.

Note: The reader is directed to the Technical Correspondence section of this issue for letters from J. C. Winterton and Ivan H. Mann III related to "Price/performance patterns of U.S. computer systems" by E. G. Cale, L. L. Gremillion, and J. L. McKenney.

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Reference

1. Cale, E. G., Gremillion, L. L., and McKenney, J. L. Price/performance patterns of U.S. computer systems. *Comm. ACM 22*, 4, (April 1979), 225–233.

ACM 1979-1980 GEORGE E. FORSYTHE STUDENT PAPER COMPETITION AWARD

The eighth annual George E. Forsythe Student Paper Competition was administered by a committee of graduate students from the University of California, Los Angeles. In all, nineteen papers were submitted to the Committee. All of the authors are thanked for their efforts.

It was particularly hard to single out one of these three articles as the first prize winner of the competition. However, the committee was unanimous in finally selecting the paper, "Automatic Extension of an ATN Knowledge Base" by Gail E. Kaiser, currently a graduate student at Carnegie-Mellon University, as the truly outstanding paper of the Competition. Her paper combines originality of material, excellent technical competence, and an unusually clear manner of presentation on subject matter which is of wide interest to the readership of *Communications of the ACM*. Kaiser will receive an all-expense paid trip to ACM '81 in Los Angeles where she will receive a certificate at the opening session. In addition, she will receive a cash award of $500.

The two other papers selected by the committee for publication were, for second prize, "An Abstract Programming Model" by Christopher E. Rothe, formerly of the University of Colorado, Boulder and, for third prize, "Shuffle Language, Petri Nets, and Context-Sensitive Grammars" by Jay Gischer of the University of Washington (now a graduate student at Stanford University).

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The 1979–1980 Student Editorial Committee Co-Chairmen were Stephen Kiser, Daniel Weise, and David Butterfield.