Estimation of Structure-Profit Relationships: Comment

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Recently, the Federal Trade Commission (*FTC*) has accused breakfast cereal manufacturers of illegal monopolization (1971). A major basis for the charge is the *FTC* belief that high advertising expenditures by the companies create effective entry barriers. One *FTC* study (1969) reached this conclusion after finding that the coefficient of the advertising/sales ratio in a multiple regression equation explaining firm profit rates was positive and significant. Several other of these so-called market structure-performance studies have recently been completed (Marshall Hall and Leonard Weiss, Vernon (1972)). However, in a recent issue of this *Review*, Blake Imel and Peter Helmberger (hereafter, I-H) presented some findings which cast serious doubt upon the validity of these studies. According to their carefully specified profit equation for a diversified firm, the significance of advertising as a barrier to entry depends critically on the size of an unknown parameter termed the "*omega* ratio." For example, for one specification of the profit rate equation, the estimated *t*-ratios varied from 3.31 to 1.86 to 1.29 as the *omega* ratio ranged from 0.0 to 0.5 to 0.8. Since I-H were unable to estimate this ratio and it is not known a priori, it is important to seek evidence as to its magnitude.

In this paper, after a brief review of the I-H model, we suggest a method for estimating the *omega* ratio. We then present some estimates for a body of data similar to that used by I-H. Our results indicate that the estimated ratio (and hence the significance of the estimated coefficients) is approximately the same for two alternative specifications of the model. More importantly, the estimated advertising coefficients, conditional on our estimated *omega* ratios, are positive and statistically significant. Thus, this note tends to corroborate the hypothesis that advertising serves as an effective barrier to entry.

I. The Imel-Helmberger Model

At the cost of placing severe restrictions on the profit equation of a diversified firm, I-H are able to specify the off-diagonal as well as the diagonal elements of the error variance-covariance matrix. Hence, except for the problem of estimating the *omega* ratio and therefore the variance-covariance matrix, generalized least squares (*GLS*) is the appropriate estimation technique.

For a firm specialized in one market, I-H write the profit rate equation as

$$(1)\qquad R_i = a + bE_i + cM_i + u_i$$

where

- R_i = the profit rate of the ith firm
- M_i = a market-related structural variable, such as the concentration ratio, of the ith firm
- E_i = a firm-related variable, such as size, of the ith firm
- u_i = the total error term, representing both firm-related and market-related omitted variables

A distinctive feature of their model is the assumption that the error term is composed of two components,

$$u_i = e_i + m_i$$

where e_i is that part of the error term due to the omission of firm-related variables and m_i is that part due to the omission of market-related variables. It is assumed that

$$Eu_i = Em_i = Ee_i = 0$$

and

$$\sigma_u^2 = \sigma_m^2 + \sigma_e^2$$

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I-H construct the profit equation for the *i*th diversified firm from the simple sum of profits of its divisions. Thus the profit equation of the *i*th diversified firm consisting of two divisions—the *g*th division operating in market *j* and the *k*th division operating in market *h*—is given by

$$(2)\quad R_{id} = a + b(D_{ij}M_j + D_{ih}M_h) + c(D_{ij}E_{gj} + D_{ih}E_{kh}) + D_{ij}m_j + D_{ih}m_h + D_{ij}e_{gj} + D_{ih}e_{kh}$$

where

D_{ij} = the share of the diversified firm's total sales accounted for by its sales in the *j*th market

D_{ih} = the share of the diversified firm's total sales accounted for by its sales in the *h*th market

Generalized to T markets the structure of the variance-covariance matrix of the error term resulting from this model is of special importance. The *i*th diagonal element is:

$$(D_{i1}^2 + D_{i2}^2 + \dots + D_{iT}^2)\sigma_u^2$$

The expression in parenthesis is a Herfindahl measure of product diversification, or H_i. For a firm specialized in one market, $H_i = 1$ and hence σ_u^2 is the variance of the error term. A typical off-diagonal element is simply the covariance term for two firms. For example, if firms i and j have at least one market in common, the element is the sum of the cross-products of D_{ik} for the firms' common markets.

$$\sigma_m^2 \sum_{k=1}^{T} D_{ik}D_{jk}$$

If σ_u^2 is factored out of the variance-covariance matrix, the diagonal elements become the H measures of product diversification for the firms in the sample. The typical off-diagonal element becomes

$$K \sum_{k=1}^{T} D_{ik}D_{jk}$$

where K is the *omega* ratio, $K = \sigma_m^2/\sigma_u^2$. Hence, knowledge of K and D_{ik} is sufficient to compute the entire variance-covariance matrix.

II. Estimation Procedure

Our procedure for estimating the *omega* ratio is a simple adaptation of the two-stage technique described by Marc Nerlove, p. 373. In the first stage we account for the effect of the omitted market variables by treating m_k as parameters, and by estimating them using weighted least squares (*WLS*). These in turn are used to estimate σ_m^2 and thereby K and the variance-covariance matrix. Our procedure differs from that of Nerlove in that the I-H specification requires weighted dummies as well as weighted least squares. The second stage consists of using the estimated variance-covariance matrix and applying generalized least squares. The remainder of this section will be devoted to a fuller discussion of the first stage.

Generalizing the profit rate equation for the *i*th diversified firm selling in up to T markets yields:

$$(3)\quad R_{id} = bM_i + cE_i + m_1D_{i1} + \dots + m_TD_{iT} + v_i$$

where

$$M_i = \sum_{k=1}^{T} D_{ik}M_k, \qquad E_i = \sum_{k=1}^{T} D_{ik}E_{ik},$$

$$v_i = \sum_{k=1}^{T} D_{ik}e_{ik}$$

with

$$Ev_i = 0$$

$$\text{var } v_i = \sigma_e^2 \sum_k D_{ik} = \sigma_e^2 H_i$$

Regarding m_k as parameters to be estimated, equation (3) can be estimated using weighted least squares[1] where the appropriate weights are $1/\sqrt{H_i}$.

[1] In Nerlove's first stage, the role of D_{ik} in equation (3) is played by a zero-one dummy variable. In the context of the I-H model, such zero-one dummies would be appropriate only if firms were specialized in one market in which case the coefficient of a dummy variable (plus the constant) would be the profit rate intercept for that market. However, the profit rate intercept for a diversi-

Applying *WLS* to (3) yields an estimated intercept term $\hat{m}_k$ for each of T markets. Thus our estimator of the variance of the error terms due to omitted market variables is given by

$$\hat{\sigma}_m^2 = \frac{1}{T}\sum_{k=1}^{T}\left(\hat{m}_k - \frac{1}{T}\sum_{k=1}^{T}\hat{m}_k\right)^2$$

The residual variance[2] from *WLS* estimation of (3), unadjusted for degrees of freedom, is used as an estimate of the variance of the error terms due to omitted firm variables, $\hat{\sigma}_e^2$. Hence an estimate of the *omega* ratio is

$$\hat{K} = \hat{\sigma}_m^2/(\hat{\sigma}_m^2 + \hat{\sigma}_e^2)$$

This estimate of the *omega* ratio along with D_{ik} is used to calculate the estimated variance-covariance matrix, thus completing the first stage.

III. Illustration

The sample of firms that we use to illustrate the procedure is described fully in a paper by Vernon and R. E. M. Nourse. Briefly the sample consists of 57 large manufacturing firms engaged in selling food, beer, liquor and wine, tobacco, soaps and detergents, household supplies, and toiletries. The data cover the period 1963–69 and were obtained from the usual trade and governmental sources. Industry variables were constructed at the 4-digit SIC level of aggregation. The variables are defined below.

Dependent

R = the firm's net income divided by shareholders' equity, averaged over the years 1963–68

Independent

D_{ik} = the share of the ith firm's sales sold in market k

DC = a dummy variable that equals unity if the weighted[3] average concentration ratio of the firm's product markets is greater than 50, and zero otherwise (1966 4-firm concentration ratios).

CAS = the 1969 advertising/sales ratio of the firm.

AS = the weighted average industry advertising/sales ratio of the firm's product markets

LS = the reciprocal of the logarithm of 1968 total assets of the firm

We examined regressions for two specifications. In model A, the company advertising/sales ratio, CAS, is used as an independent variable along with a market concentration and a firm size variable; in model B, CAS is replaced by AS, the weighted industry advertising/sales ratio.[4]

We report our estimation results for stage one only summarily. Many variations of the stage one procedure were attempted.[5] In all cases the *omega* ratio estimates for models

fied firm is a linear combination of market intercepts. Therefore, in equation (3) each firm has a weighted dummy variable for each market in which it participates, the weights being the share of firm sales in that market. Because we have 40 markets and only 57 observations, the use of a dummy variable for each market would leave us with too few degrees of freedom. A reasonable compromise seemed to be to aggregate the 40 four-digit markets into 11 three-digit markets. Hence, we used 11 dummy variables rather than 40.

[2] Of course, the residual variance must be adjusted to correct for the weighting procedure.

[3] The weights used are the estimated shares of the firm's total sales in each of the 40 4-digit SIC industries covered.

[4] The two advertising variables would appear to raise some ambiguities with respect to the I-H scheme of classifying all variables as either firm or market related. For example, AS might be considered to be a bit of both.

[5] Among the variations that we tried were: *WLS* with the weighted dummies representing markets (the weights were $1/\sqrt{H_i}$), and *CLS* with both weighted and unweighted dummies. Imel has pointed out that DC is incorrectly constructed *if* one wishes to test the hypothesis that firms earn higher profits in markets where concentration exceeds 50 percent. Rather than defining the zero-one dummy variable on CR (as we have done), one should first define the dummies for each market and then construct the firm's variable (DW) as a weighted average of the market dummies. We therefore estimated our regressions substituting DW for DC and found only slight differences in the results. Given the simple correlation coefficient between DW and DC of .96, this is not unexpected. We should note, however, that the DW variable did tend to yield slightly higher t-values. For example, the DW t-value in the regression of the profit rate on DW, AS, and CAS was 1.62 as compared with 1.5 for DC.

TABLE 1—MULTIPLE REGRESSION EQUATIONS EXPLAINING FIRM PROFIT RATES USING CLASSICAL LEAST SQUARES (*CLS*) AND USING GENERALIZED LEAST SQUARES (*GLS*) WITH FOUR ALTERNATIVE SPECIFICATIONS OF THE VARIANCE-COVARIANCE MATRIX OF THE ERROR TERM

Estimation Procedure	Assumed Value of $\hat{K}$	Intercept	*DC*	*AS*	*CAS*	*LS*	R^2	Equation Number
CLS		.141	.009 (.44)		0.806 (4.27)[a]	−.260 (−1.50)	.28	(1)
GLS	0.0	.124	.019 (1.13)		0.790 (4.45)[a]	−.210 (−1.33)	.42	(2)
GLS	0.23	.138	.022 (1.09)		0.703 (3.78)[a]	−.268 (−1.69)	.38	(3)
GLS	0.5	.153	.019 (.83)		0.698 (3.68)[a]	−.337 (−2.06)[a]	.36	(4)
GLS	0.8	.181	.113 (.37)		0.722 (3.73)[a]	−.474 (−2.71)[a]	.32	(5)
CLS		.105	.028 (1.50)	0.833 (5.01)[a]		−.178 (−1.08)	.34	(6)
GLS	0.0	.111	.026 (1.58)	0.838 (4.96)[a]		−.185 (−1.21)	.46	(7)
GLS	0.21	.121	.023 (1.13)	0.823 (3.42)[a]		−.211 (−1.31)	.35	(8)
GLS	0.5	.132	.018 (.73)	0.883 (2.61)[a]		−.255 (−1.49)	.29	(9)
GLS	0.8	.145	.011 (.32)	1.091 (2.04)[a]		−.335 (−1.82)	.20	(10)

Note: The numbers in parentheses are *t*-ratios; the number of observations is 57.
[a] Indicates significance at the .025 level for a one-tail *t*-test.

A and *B* lay in the range of 0.173 to 0.247. For example, one set of estimates for model *A* yielded $\hat{\sigma}_m^2 = .0012$, $\hat{\sigma}_e^2 = .0043$, and $\hat{K} = 0.217$. The corresponding estimates for model B were $\hat{\sigma}_m^2 = .0012$, $\hat{\sigma}_e^2 = .0045$, and $\hat{K} = 0.207$. For use in stage two, we selected the following representative values of $\hat{K}$:

	$\hat{K}$ (the *omega* ratio)
Model *A*	0.23
Model *B*	0.21

To permit comparison of our results with those of I-H, we estimated models *A* and *B* using classical least squares (*CLS*) and using *GLS* conditional on the following values of the *omega* ratio: 0.00, 0.23 or 0.21, 0.50, and 0.80. These equations are presented in Table 1.

For every equation the signs of our estimated coefficients agree with a priori expectations. As I-H found, the significance of the concentration ratio and the advertising variables tend to fall as the *omega* ratio increases. Contrary to the I-H findings, the advertising/sales ratio remained significantly positive at a .025 level even when the *omega* ratio was set at 0.80. It is interesting to note that the *GLS* results for $K = 0.00$ (equivalent to *WLS*) and for $K = 0.23$ (or 0.21) are so similar that no qualitatively different conclusions can be drawn.

In *GLS* estimation of the I-H model, *ceteris paribus* the larger the *omega* ratio the more weight is given to the off-diagonal elements of the variance-covariance matrix. That is, the more important are the omitted market variables relative to the omitted firm variables (i.e., the bigger is K), the more we need to take into account the interdependence among error components for firms selling in the same markets. A large K emphasizes this interdependence at the expense of differences among firms' levels of diversification and conversely. In market structure-performance studies prior to that of I-H, the usual practice was to use weighted least squares (i.e., $K=0$) and to neglect the off-diagonal elements of the variance-covariance matrix altogether. Under the I-H specification, this problem would be misleading if in fact K were large. The evidence we have put forward in this note suggests that although K is not zero, nonetheless it is not large enough to make the *GLS* results very different from those for *WLS*. However, we should emphasize that our results are specific to our sample of data.

A final caveat on the use of the I-H model is in order. In order to use their model, it is necessary to have an unambiguous classification of the independent (and omitted) variables as being either firm-related or market-related. This does not always appear to be possible. We have already noted the doubtful classification of the advertising variables in this respect. Another example is a measure of firm size: the *average* size of firms in a market might be viewed as a market-related variable and deviations from the average as firm-related, or the measure might be viewed solely as a firm-related variable (following I-H).

Finally, we do consider the I-H work to be a useful contribution to the growing literature on market structure-performance studies where observations are on firms rather than industries. If for no other reason, I-H are to be commended for highlighting the rather severe assumption that the profit equation of a diversified firm is a simple *linear* combination of profit equations of the firm's divisions.

REFERENCES

M. Hall and L. W. Weiss, "Firm Size and Profitability," *Rev. Econ. Statist.*, Aug. 1967, *49*, 319–31.

B. Imel and P. Helmberger, "Estimation of Structure-Profit Relationships with Application to the Food Processing Sector," *Amer. Econ. Rev.*, Sept. 1971, *61*, 614–27.

M. Nerlove, "Further Evidence on the Estimation of Dynamic Economic Relations from a Time Series of Cross Sections," *Econometrica*, Mar. 1971, *39*, 359–82.

J. M. Vernon, *Market Structure and Industrial Performance: A Review of Statistical Findings*, Boston 1972.

——— **and R. E. M. Nourse**, "The Effect of Market Structure on Profit Rates of Advertising Intensive Firms," *J. Ind. Econ.*, forthcoming.

Federal Trade Commission, *Economic Report on the Influence of Market Structure on the Profit Performance of Food Manufacturing Companies*, September 1969.

———, *New York Times*, Jan. 25, 1971, p. 1.