THE STRUCTURAL STABILITY OF THE CONCENTRATION-PERFORMANCE RELATIONSHIP IN FOOD MANUFACTURING

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INTRODUCTION

The literature of industrial organization is replete with analyses of the relationship between seller concentration and market performance. Most researchers have hypothesized a continuous linear relationship between profitability and concentration and have estimated that relationship accordingly. However, several researchers have hypothesized that the parameters (intercept and/or slope coefficients) relating concentration to profitability are not constant over the range of concentration values. A rationale for the latter view is provided by Chamberlin's theory of oligopoly. High concentration causes firms to recognize their interdependence and mutual interest in maintaining prices high enough to yield supranormal profits. A reduction in concentration to some "critical" level leads firms to ignore their direct influence upon prices, and, as a consequence, prices and profits "will fall at once to the competitive level" (Chamberlin, p. 48). Similarly, Blair has argued that the concentration-profits relationship may be discontinuous; that is, once a critical level of concentration is reached, further increases in concentration do not affect behavior and, thus, performance.

As discussed by Rhoades, the structural stability of the concentration-performance relationship has important implications for antitrust policies relating to divestitures and mergers. For example, if this relationship is discontinuous, the antitrust authorities should be most attentive to mergers in industries in which concentration is less than, but approaching, the critical level. Conversely, a continuous linear relationship implies that an increase in concentration via merger would have the same effect on profitability—regardless of the level of concentration.

Previous studies of the constancy of the concentration-profits relationship have yielded conflicting results. These studies typically have used dummy variables to allow for intercept and/or slope shifts, or partitioned samples according to the level of concentration. A shortcoming of this approach is that prior information is required as to the level(s) of concentration at which the change(s) in the relationship occurs. Enumeration and estimation of models with all possible combinations of slope and intercept shifters or all possible sample partitions is not practical. Researchers who have dealt with this problem by testing for intercept and/or slope changes at a few selected concentration levels could only hope that the level(s) at which a change in structure occurs was selected for analysis. Also, this approach—searching over a sample for a desired result and than selecting the best fit—invalidates the usual statistical tests of significance (White, p. 63).

This paper evaluates the structural stability of the concentration-profits relationship in food manufacturing. In testing for structural stability, we employ several statistical techniques that appear to offer advantages over the methods used in previous analyses of this sort. First, previous tests of the structural stability of the concentration-profits relationship are reviewed. Next, some alternative methods for testing structural stability are discussed. These methods are then applied to food manufacturing firm data. Finally, we offer our conclusions.

PREVIOUS TESTS OF PARAMETER CONSTANCY

Bain apparently was the first researcher to identify a discontinuous concentration-profitability relationship. He found only a weak linear bivariate relationship between 8-firm concentration ratios and profit rates. However, after grouping his industry profit data by 8-firm concentration ratio deciles, he found a significantly higher profitability among industries with 8-firm concentration ratios above 70 percent. Bain's results were later confirmed in a study by Meehan and Duchesneau. After preliminary screening of 60-, 70-, and 80-percent 8-firm concentration ratios as potential "critical" levels, they found evidence of a discontinuous concentration-profitability relationship when their sample was partitioned at the 70-percent concentration level. They also found that changes in 8-firm concentration above or below the 70-percent level had no effect on profitability. They also screened 50-, 55-, 60-, and 65-percent 4-firm concentration

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ratios in their analysis. Although their statistical results were equivocal, they concluded that the critical 4-firm ratio was 55 percent.

Rhoades and Cleaver screened 20-, 30-, 40–59-, 80-, and 90-percent 4-firm concentration ratios as alternative potential breakpoints in the concentration-profitability relationship. Treating concentration as a dichotomous variable, they found that variable significant regardless of the breakpoint used, with the 51-percent breakpoint yielding the highest adjusted R^2. Further analysis indicated that changes in concentration below 51 percent had no effect on profitability, but that concentration changes above that level did affect profitability.

After preliminary screening of ranges of 4- and 8-firm concentration ratios at 5-percent intervals, Dalton and Penn concluded that 45-percent 4-firm and 60-percent 8-firm concentration ratios were the most likely critical levels. Their analysis revealed that average profits were greater for firms operating in markets with high concentration (4-firm concentration > 45% or 8-firm concentration > 60%). They also found that changes in concentration had no effect on profitability within high and low concentration groups.

Based on preliminary screening, Rhoades identified 50-percent 4-firm concentration as a potential critical value. Although he found a significant dichotomy in his estimated concentration-profitability relationship at that concentration level, the continuous linear specification of that relationship had the higher adjusted R^2. Also, Rhoades found no evidence of differential responses of profitability to changes in concentration between industries with 4-firm concentration above and below 50 percent. Additional support for the continuity of the concentration-profitability has been provided by Collins and Preston (pp. 103–6), and Kilpatrick.

In order to avoid the possible invalidation of statistical tests arising from the general approach used in the above studies, White proposed use of the likelihood ratio technique for estimating the switching point in discontinuously switching regression regimes (Quandt, 1958, 1960). This test is strictly appropriate only when it is believed that the regression relationship follows two separate regimes and the change between regimes is abrupt at some unknown point. Using this technique, White found evidence of critical 4- and 8-firm concentration ratios in the ranges 56–59 percent and 70–72, respectively.

To summarize, previous evidence indicates the presence of critical 4- and 8-firm ratios in the ranges from 45–59 percent, and 60–72 precent, respectively. Other evidence points to a continuous linear relationship between concentration and profitability. However, the general approach used in most of these studies calls into question the validity of the statistical tests upon which their conclusions are based.

ALTERNATIVE TESTS OF STABILITY

In this paper, two types of tests are employed to determine whether the concentration-profits relationship in food manufacturing is subject to structural change, and, if so, at what level(s) of concentration the change(s) occurs. The tests are the CUSUM and CUSUMSQ tests, and the log-likelihood ratio test. These tests require that the observations to which they are applied possess a natural ordering index. In most previous applications of these tests, that index has been time. In the present context, it is assumed that the ordering index is the level of concentration. Since these tests are covered in detail elsewhere, only a brief sketch of each is given here.

The CUSUM and CUSUMSQ tests were devised by Brown, et al. The null hypothesis to be tested is that the regression coefficients are constant over the natural order: the alternative hypothesis is that the parameter(s) are not constant. If the null hypothesis is false and parameter change is not accounted for in estimation over the entire sample, the regression residuals should behave in an aberrant fashion beyond the point of parameter change. However, Brown et al., point out that these residuals are not very sensitive to small or gradual parameter changes. They argue that analyses performed with recursive residuals are more likely to detect such changes. The recursive residuals are standardized, one-step-ahead-in natural order prediction errors from regressions, using successively larger samples. If the null hypothesis of parameter constancy is correct, then the recursive residuals have an expected value of zero. On the other hand, if the parameters are not constant, the recursive residuals have non-zero expected values following the parameter change.

Two tests based on these recursive residuals have been suggested by Brown, et al. The first of these involves a plot of the cumulative sum (CUSUM) of recursive residuals against the order variable and checking for deviations from the expected value of zero. Symmetric confidence lines above and below the zero value allow definition of a confidence band beyond which the CUSUM plot should not pass, for a selected significance level, if the regression parameters are stable. A related test involves plotting the cumulative sum of squared (CUSUMSQ) recursive residuals against the ordering variable. The CUSUMSQs have expected values ranging in a linear fashion from zero at the first-ordered observation to one at the end of the sampling interval if the null hypothesis is correct. Again, symmetric confidence lines above and below the expected value line define a confidence band beyond which the CUSUMSQ plot should not pass, for a selected significance level, if the null hypothesis of parameter constancy is true. In both the CUSUM and CUSUMSQ tests, the points at which the plots cross the confidence lines give some indiction of value(s) of the ordering variable associated with parameter change. Monte Carlo simulations indicate that the CUSUMSQ is the more powerful of the two tests (Garbade, p. 57).

The final test employed here is a log-likelihood ratio test (Quandt, 1958, 1960; White). As discussed above, this test is strictly appropriate only when it is believed that the regression relationship follows two separate regimes, and that the change between regimes is abrupt at some unknown "critical" value of the ordering variable.[1] The estimated "critical" value of the ordering variable is the value for which the corresponding log-likelihood ratio reaches a minimum. Although no exact test for the minimum of this ratio is known, a graph of the ratio against the corresponding ordering variable gives evidence about whether a parameter change occurs abruptly or gradually, according to whether the graph is jagged or smooth, respectively.

EMPIRICAL ANALYSIS

In testing the structural stability of the concentration-profitability relationship in food manufacturing, the data for 97 food manufacturing firms compiled by the Federal Trade Commission (FTC) are employed. The data are for 1950 and are admittedly dated. However, this is one of the few published data sets containing the profitability of individual firms. Use of firm data avoids problems inherent in the use of industry price-cost margins (Scherer). The data are concurrent, or nearly so, with the data used in earlier studies to ascertain critical-concentration levels (Kilpatrick; Dalton and Penn; Meehan and Duchesneau). Thus, comparison of the results determined in the present study and those from earlier studies appears warranted.[2] The model applied to the firm data is essentially that used by the FTC staff.

$$P = b_1 + b_2CR4(8) + b_3MS + b_4A + b_5D + b_6FD + b_7S$$

where

P = profit rate of the firm specified as (net income + interest expense)/(shareholders' equity + long-term debt),

CR4(8) = weighted average of seller concentration ratios in the firm's product markets, alternatively specified as CR4 = 4-firm concentration, and CR8 = 8-firm concentration,

MS = weighted average of the firm's relative market share in its product markets,

A = weighted average of industry advertising-to-sales ratios in the firm's markets,

D = a measure of growth in demand in markets served by the firm,

FD = a measure of firm diversification over markets defined at the three-digit SIC level,

S = firm size, measured as the reciprocal of the logarithm of the firm's total assets.[3,4]

High concentration is hypothesized to facilitate collusion among firms within an industry; low concentration is hypothesized to cause firms to act independently. Thus, the expected sign of b_2 is positive. A positive relationship is expected between profitability and relative market share as the latter reflects the levels of product differentiation and/or scale economies enjoyed by the firm relative to its competitors. The advertising variable is included as a measure of the barriers to entry arising from product differentiation created by advertising, with a positive relationship expected between that variable and profitability. Growth in product demand is also expected to have a positive effect on profits. The FTC staff argued that the expected net relationship between profitability and firm diversification should be considered indeterminant, because increased resource utilization and risk reductions arising from diversification may have offsetting effects on profitability. Finally, firm size is expected to have a positive effect on profitability in view of the fact that larger firms can overcome absolute-capital-requirements barriers to entry, and also achieve economies of size. Note that the measure of firm size used here, the reciprocal of the log of the firm's total assets, leads to an expected negative sign for b_7.

The FTC staff found evidence of heteroskedastic disturbances when estimating equation (1). To correct this problem, they weighted each variable and the constant term in equation (1) by the fourth root of firm total assets. This weighting scheme introduces a new explanatory variable, W = the fourth root of firm total assets, and re-

[1] Note that the alternative hypothesis for the CUSUM and CUSUMSQ tests is more general than that for the log-likelihood ratio test. The former tests should detect departures from parameter constancy regardless of whether the departures are a single abrupt change or a series of gradual parameter changes.

[2] Analyses performed with these data would have only limited value for antitrust policy makers unless the critical concentration level is stable over time. However, in order to determine whether that level is stable, a benchmark must be established. The statistical techniques employed here should provide a better means of establishing that benchmark than do the techniques used in earlier studies. If the requisite data become available, the application of the techniques used here to more recent data could shed light on the temporal stability of critical concentration levels.

[3] The reader is referred to the FTC report for a more complete description of the variables appearing in equation (1).

[4] The use of weighted concentration ratios is potentially troublesome. A reviewer has noted that the use of these ratios requires the assumption that the critical concentration ratio is invariant across industries. However, this assumption is implicit in all previous studies that have used industry data to determine critical concentration levels. A precedent for the use of these ratios in estimating critical concentration levels may be found in Dalton and Penn.

quires that the equation be estimated without an intercept. In the following, weighted regressions are used since the presence of heteroskedasticity may complicate interpretation of the tests listed in the preceding section.

The estimated weighted regressions for the alternative formulations of Equation (1) are as follows:[5]

$$
\begin{aligned}
(2)\quad P\,W = {} & -.561W + .072CR4\,W + \\
& (-.21) \qquad (2.19)^{*} \\
& .098MS\,W + 1.25A\,W - \\
& (3.74)^{**} \qquad (3.05)^{**} \\
& .004D\,W - .025FD\,W + \\
& (-.33) \qquad (-.93) \\
& 6.28S\,W \\
& (.85) \\
& R^2 = .89
\end{aligned}
$$

$$
\begin{aligned}
(3)\quad P\,W = {} & -2.46W + .088CR8\,W + \\
& (-.84) \qquad (2.59)^{**} \\
& .099MS\,W + 1.18A\,W - \\
& (3.80)^{**} \qquad (2.94)^{**} \\
& .000D\,W - .029FD\,W + \\
& (-.00) \qquad (-1.08) \\
& 6.23S\,W \\
& (.85) \\
& R^2 = .90.
\end{aligned}
$$

The results are comparable to those obtained by the FTC. Specifically, the coefficients associated with concentration, relative market share, and advertising have the expected positive signs and are significant at or below the 5 percent level in equations (2) and (3). The coefficients associated with market growth and firm size have anomalous signs in equations (2) and (3); however, these coefficients are not significant. Finally, the coefficient associated with diversification is insignificant in both equations.

Displayed in Figures 1–3 are plots of the CUSUMs, CUSUMSQs, and log-likelihood ratios, when the data used in estimating equation (2) are ordered by decreasing values of CR4. Figures 4–6 display similar plots, when the data used in estimating equation (3) are ordered by decreasing values of CR8. These graphs motivate the following comments.

The CUSUM tests (Figures 1, 4) provide no indication of instability in the relationship between profitability and concentration, regardless of whether the latter is measured at the 4- or 8-firm level. However, the more powerful CUSUMSQ tests indicate structural change occurring at observation 27 in Figure 2 and observation 25 in Figure 5. These observations correspond to 4-firm concentration of 64 percent and 8-firm concentration of 78 percent.[6] From Figure

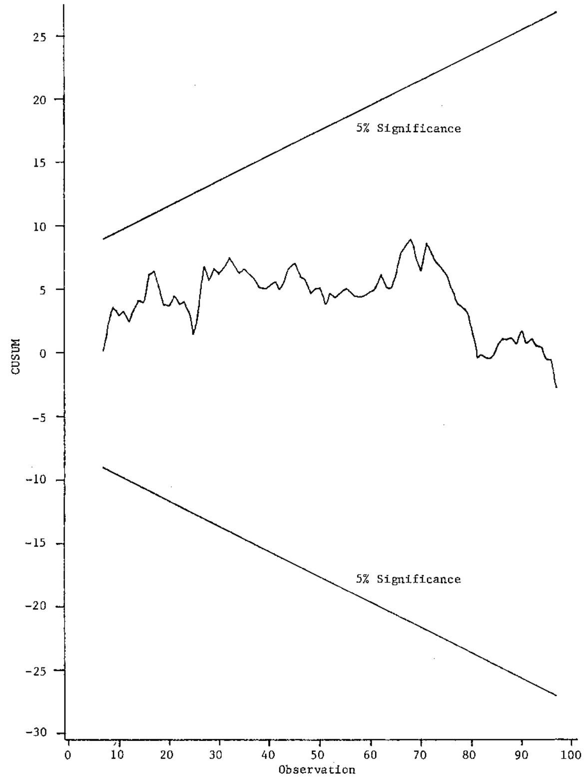

FIGURE 1. CUSUM, Forward Recursion, Equation (2)

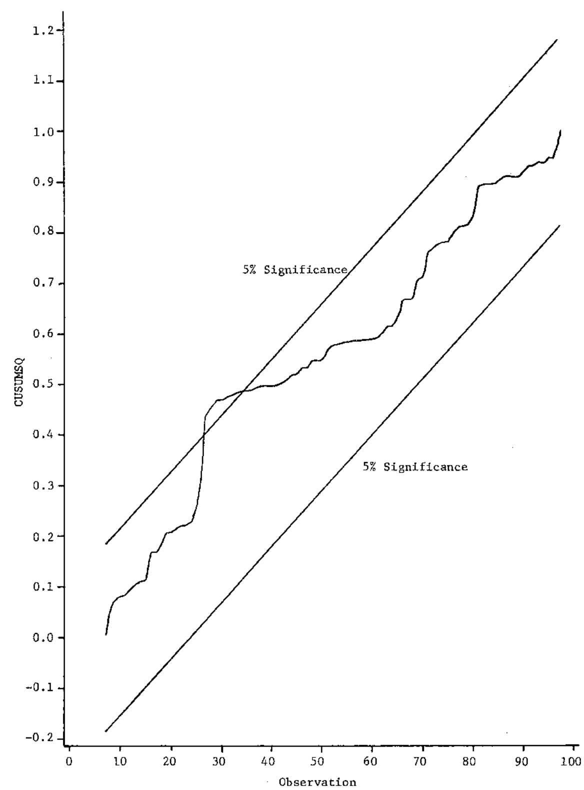

FIGURE 2. CUSUMSQ, Forward Recursion, Equation (2)

[5] Figures in parentheses are t-ratios. Also, *(**) denotes significance at the 5(1) percent level.

[6] The CUSUM and CUSUMSQ tests were also performed on the backward recursive residuals, which are based on regressions run from the last ordered observation back down to the first. The results for these tests generally conform to the results reported here.

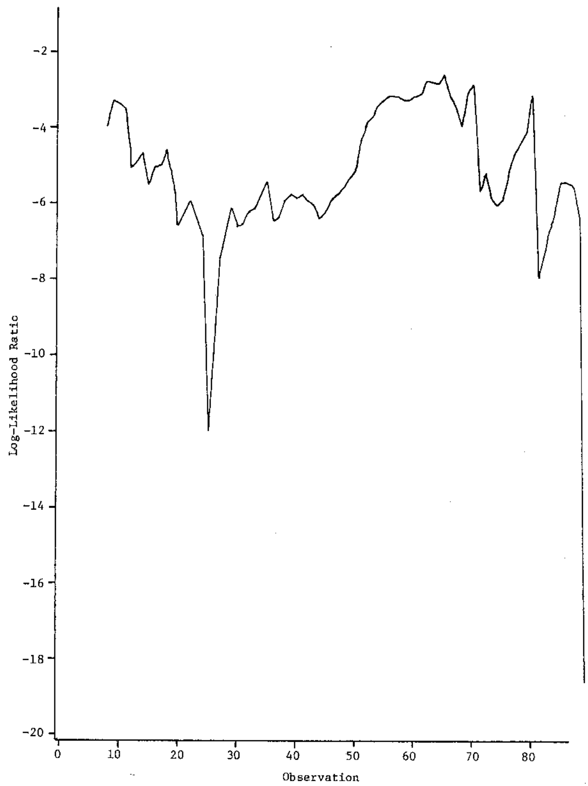

FIGURE 3. Log-likelihood Ratio, Equation (2)

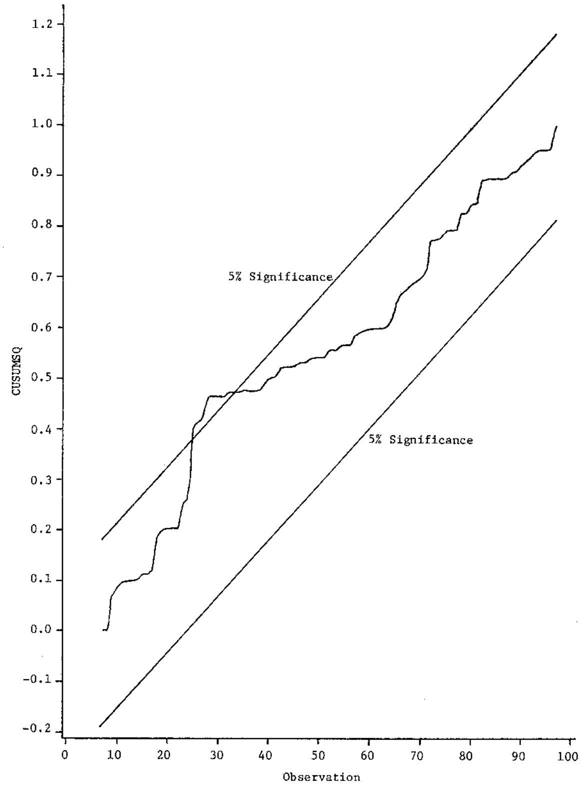

FIGURE 5. CUSUMSQ, Forward Recursion, Equation (3)

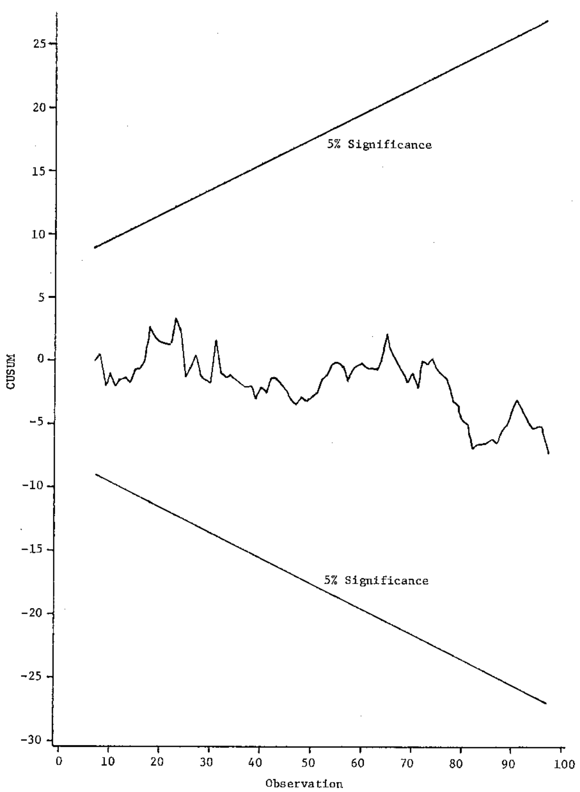

FIGURE 4. CUSUM, Forward Recursion, Equation (3)

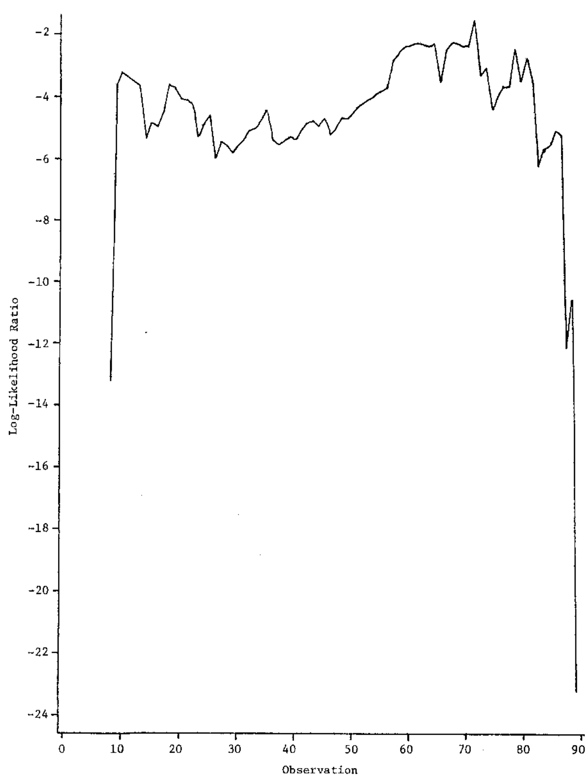

FIGURE 6. Log-likelihood Ratio, Equation (3)

3, the log-likelihood ratio for equation (2) is relatively jagged, and achieves a minimum (ignoring "starting-up" problems) at observation 25, where CR4 = 64 percent. The log-likelihood ratio for equation (2) in that there are no abrupt changes in the former ratio. This may indicate that any parameter changes in equation (3) are more gradual than those in equation (2). However, the log-likelihood ratio in Figure 6 achieves a local minimum at observation 26, where CR8 = 78 percent. In summary, both the CUSUMSQ and log-likelihood techniques point to structural changes in equations (2) and (3), when CR4 = 64 percent and CR8 = 78 percent, respectively.

The results of estimating equations (2) and (3) with data partitioned at the "critical" concentration ratios identified above are shown below as equations (4), (5), and (6), (7), respectively.

For CR4 > 64%,

$$
\begin{array}{llll}
(4) & PW = & 2.25\ W - & .139CR4\ W + \\
 & & (.23) & (-1.14) \\
 & & .251MS\ W + & 2.34A\ W + \\
 & & (3.39)^{**} & (2.84)^{**} \\
 & & .013D\ W + & .002FD\ W + \\
 & & (.37) & (.02) \\
 & & 24.50S\ W & \\
 & & (1.00) & \\
 & & R^2 = .94. &
\end{array}
$$

For CR4 ≤ 64%,

$$
\begin{array}{llll}
(5) & PW = & -4.23\ W + & .149CR4\ W + \\
 & & (1.26) & (3.10)^{**} \\
 & & .059MS\ W + & 1.23A\ W - \\
 & & (2.08)^{*} & (2.36)^{*} \\
 & & .002D\ W - & .021FD\ W + \\
 & & (-.11) & (-.73) \\
 & & 0.72S\ W & \\
 & & (1.28) & \\
 & & R^2 = .89. &
\end{array}
$$

For CR8 > 78%,

$$
\begin{array}{llll}
(6) & PW = & 24.28\ W - & .152CR8\ W + \\
 & & (1.41) & (-.60) \\
 & & .120MS\ W + & 1.23A\ W + \\
 & & (1.29) & (1.44) \\
 & & .043D\ W - & .107FD\ W - \\
 & & (.94) & (-1.33) \\
 & & 19.06S\ W & \\
 & & (-.69) & \\
 & & R^2 = .93. &
\end{array}
$$

For CR8 ≤ 78%,

$$
\begin{array}{llll}
(7) & PW = & -5.47\ W + & .101CR8\ W + \\
 & & (-1.61) & (2.42)^{**} \\
 & & .090MS\ W + & 1.21A\ W + \\
 & & (3.24)^{**} & (2.30)^{*} \\
 & & .006D\ W - & .018FD\ W + \\
 & & (.42) & (-.64) \\
 & & 14.48S\ W & \\
 & & (1.90) & \\
 & & R^2 = .89. &
\end{array}
$$

The hypothesis that the coefficients of equations (4) and (5) are homogeneous cannot be rejected at the 5-percent level via an F-test (calculated F = 2.08); however, that hypothesis can be rejected at the 10-percent level. Note that the insignificant coefficient for CR4 in equation (4) lends some support to Blair's argument that increases in concentration above the critical level do not affect performance. The coefficient for CR8 in equation (6) also is insignificant; however, the hypothesis that the coefficients of equations (6) and (7) are homogeneous cannot be rejected at the 10-percent level (calculated F = 1.37).

CONCLUSIONS

Earlier studies of the relationship between concentration and profitability have yielded conflicting results. Changes in that relationship have been previously noted when 4-firm concentration is between 45 and 59 percent, and 8-firm concentration is between 60 and 70 percent. Other evidence indicates that the concentration-profitability relationship is continuous and linear. The evidence presented here for the food manufacturing sector is equivocal. There is some evidence that there may be a structural change in the concentration-profitability relationship when 4-firm concentration approaches 64 percent. Increases in concentration above that level may not serve to increase profitability. Much weaker evidence points to a structural change when 8-firm concentration approaches 78 percent.

That these "critical" concentration ratios are higher than those identified in earlier studies may be explained by differences in the statistical techniques used in analysis. However, the diversity of results from this and earlier studies suggests that there may be no single "critical" concentration ratio. Rather, the level of "critical" ratio, if any exists, may depend on the data sampled. Thus, the application of a single "critical" concentration ratio in antitrust actions with respect to mergers and/or divestitures may not be warranted.

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