1991

PROFIT-STRUCTURE RELATIONSHIPS IN U.S. FOOD INDUSTRIES

2142

Food industry

by

Francis Declerck and Bruce Sherrick

July 1991

The authors are Ph.D. candidate and assistant professor, respectively, in the Department of Agricultural Economics, University of Illinois at Urbana-Champaign. The usual disclaimers apply.

AAEA, 1991

#20180

PROFIT-STRUCTURE RELATIONSHIPS IN U.S. FOOD INDUSTRIES

ABSTRACT

This study examines the usefulness of concentration indices in explaining levels in price-cost margins in U.S. food industries. Cross-sectional and pooled regressions indicate that concentration at top-4-firm level, advertising, and advertising squared are the most significant variables in explaining profit. Technology variables are not significant.

PROFIT-STRUCTURE RELATIONSHIPS IN U.S. FOOD INDUSTRIES

Introduction

Observed relationships between industry structure and economic performance are often used to test hypotheses about oligopoly and market power. Several indicators and measures may be used to examine these relationships. Profit-structure relationships are important because growing firms, associated with increasing concentration, have significantly changed the food industry structure in the United States. Several economists have posited that high correlations between price-cost margins and structural variables justify anti-trust legislation because concentration inducing these margins leads to reduction in consumer surplus. Thus, this study examines the usefulness of concentration indices as predictors of levels in price-cost margins in the U.S. food industries.

The remainder of the paper is organized as follows. First, the statistical model and literature review are presented. Second, the data are described. Third, estimation of the parameters of the model is discussed. Finally, a summary of results is given and conclusions drawn from the analyses.

The statistical model

Traditional industrial organization theory attributes performance outcomes to the structure of markets and the mode of industry conduct. In a long-run competitive equilibrium, economic profits are driven to zero where prices equal marginal costs. In the short run, transitory economic profits or losses may occur. But the model of perfect competition does not fit most real world markets and the theoretical basis for the relationship between seller concentration and profits is straightforward: Successful collusion (tacit or explicit) is expected to lead to results approaching joint profit maximization. Many interpretations of positive structure-profit relationships assume that this also implies elevated prices in concentrated markets. The usual approach is to relate price-cost margins to indices that measure the structural and non-structural characteristics of markets. The use of price-cost margins to test for the existence of market power thus overcomes an estimation problem common in firm-based studies.

The basic hypothesis to be tested is that the relative excess of prices over costs is higher in more highly concentrated food industrial sectors than in less concentrated ones. Ancillary hypotheses about the relative significance of the major explanatory variables and the stability of the relationships over time are also examined. the principal exogenous variables to explain the differences in price-cost margin or economic profit (PROF) among the U.S. food industries are: concentration measured by the concentration ratio (CR) (the designation is extended to CR4 for top-4-firm and CR8 for top-8-firm ratio); minimum efficient scale (MES); advertising expenditure ratio to sales (ADS); capital intensity (KY); and industry growth (GR). Signs of these exogenous variable coefficients previously found in the literature are shown below.

Signs of exogenous variable coefficients in previous studies:

	Exogenous variables						
Authors	CR4	KY	ADS	MES	GR	$CR4^2$	ADS^2
Collins *et. al* (1968)	-	+					
Parker and Connor (1979)	+	+	+		+	+	-
Rogers(1984)	+	+	+	+	-		
Expected signs	+	+	+	?	+	?	?

Collins and Preston's monograph (1968) presents a model fit to 1958 U.S. data across 32 food manufacturing industries. The model is of the form:

$PROF = f(C, CR4, CR4^2, GEOG, KY)$,

where C is a constant and GEOG is a geographic-market index and the other variables are as defined earlier. The best fit was nonlinear involving both CR4 and $CR4^2$. All coefficients had the expected sign. Thus, the greater the capital intensity, the greater the price-cost margin for any concentration level. The equation indicates that the lowest price-cost margin occurs when CR4 equals approximately 20%, which is roughly half the level most authors assume as the competitive level.

Parker and Connor (1979) refitted the Collins-Preston model using 1972 data for 41 food-manufacturing industries. The coefficients again had the expected signs and were statistically significant except for CR4. Their equation also shows that the lowest PROF occurs when CR4 equals approximately 20%. Furthermore, these authors extended the original model by adding several variables suggested by earlier works. They used a model of the form:

$$PROF = f(C, CR4, GEOG, KY, ADS, ADS^2, GR, MES).$$

In this case, ADS was measured by the advertising as a percentage of sales of the four largest firms in each industry. Its inclusion added considerable explanatory power to the model The relationship of CR4 to margins is found to be strictly linear.

Rogers (1984), using 1972 data, found the expected signs (except for GR) using the model:

$$PROF = f\ (C, CR4, KY, ADS, GR, MES).$$

Finally, using 1963 data, Horst (1974) again finds expected results using:

$$PROF = f(C, CR4, ADS)\ .$$

All of above studies used only one year of cross sectional data containing 32 to 59 observations. Based upon these past experiences, the exogenous variables; CR4, MES, ADS, KY and GR, are chosen as candidates to explain the differences in price-cost margin or economic profit (PROF) among U.S. food industries. In addition, both 4-firm and 8-firm concentration ratios are used as explanatory variables.

Data

The data are obtained from Census of Manufactures which is conducted every five years. The measures available in the Census are: value of shipments (VOS), raw material cost (RMC), value added by manufacture (VA), payroll (PAY), new capital expenditures (CAP), inventories of the end of the year (INV), 4-firm-concentration ratio (CR4) and top-8-firm-concentration ratio (CR8). These data published by the U.S. Department of Commerce are believed to be accurate and free of error. However, some variables are calculated differently over time. Data are most recently available for the years 1977, 1982, and 1987.

Unfortunately, advertising expenditure ratio-to-sales (ADS) data have been published for only 1972 and 1977 by Rogers and Mather (1983) and reprinted by Connor *et. al* (1985). Advertising expenditures were found from Leading National Advertisers Inc. (LNA), which collects expenditures for six different media: magazines, newspaper supplements, network television, network radio, spot television, and outdoor advertising. Rogers added only the first four measures and divided that sum them by industry value of shipments (VOS) coming from the Census. However, when spot television advertising expenditures are taken into account, the total expenditure is often doubled. Moreover, the industrial classification used by LNA differs from that used in the Census. Also, Rogers matched the advertising data to the Census classification in order to produce consistent data. Unfortunately, such data are not readily available for 1982 and 1987. Thus, in this study, the types and sources of advertising data are similar, but the ratio will necessarily have a five year lag for the years 1977 and 1982 because the figures are not available for 1982 and 1987 .

The results are sometimes quite sensitive to the definition of the variables used in the model, as has been shown for ADS. In previous articles, profit (PROF) and minimum efficient scale (MES) are measured using various definitions. The choices made in this study are explained below.

Profit is defined as in Rogers's price-cost margin model and can be estimated directly from Census data at the four-digit level of aggregation in SIC code, thus minimizing a number of accounting and aggregation problems. This margin is essentially the total dollar amount of value of shipments (which is gross revenue) in an industry less raw material cost and payroll, expressed as a percentage of value of shipments

$$PROF = (VOS - RMC - PAY)/VOS$$

The minimum efficient scale is more difficult to estimate. Economies of scale relate the average unit cost of producing an item to the quantity produced. "A minimum efficient scale plant (MES) is the smallest sized plant at which minimum costs are achieved" (Connor *et al.*, 1983). In accordance with the literature, the midpoint-plant size may be used as a proxy for MES plants. The midpoint-plant MES is the plant at the median of the distribution of value added (VA) by all plants in the industry. Value of shipments for that value added class is divided by the number of establishments in the class to determine the average value of shipment per plant.

Because it is not possible to obtain consistent data for both 1977 and 1982, the ADS index will be used with a five year lag. Hence the 1972 index is used for 1977 and the 1977 index is used for 1982.

The industry growth (GR) is defined from the values of shipments :

$$GR = \frac{VOS(19n) - VOS(19n\text{-}5)}{VOS(19n\text{-}5)}$$

The capital intensity (KY) is defined by : $KY = \frac{CAP + INV}{VOS}$

The endogenous variable for the model is PROF, and the exogenous variables are CR4, $CR4^2$, MES, GR, KY, ADS, and ADS^2 .

All forty-seven industries of the U.S. food manufacturing sector are examined for the years 1977 and 1982 using the four-digit Standard Industrial Classification (SIC) from the Census of Manufactures. For these products classes, grouped data were first collected on more than 13,000 individual seven-digit SIC products. They are grouped in nine branches, with initial digits of 20. A total of 47 observations from food industries are available each year and thus 94 are examined in 1977 and 1982 pooled samples.

Estimation Procedures

The parameters for the linear models are estimated by ordinary least squares. Parameters of different models are estimated in order to locate the set of exogenous variables which best explain the differences in price-cost margin (PROF) among the U.S. food industries. Multiple linear regressions are run with 1977 data, 1982 data and with both years' pooled data. Three tests are performed to determine the significance of the regression, the significance of each coefficient, and the equality of the regressions over time.

The hypothesis that there is no relationship between PROF and the set of selected exogenous variables is tested via the hypotheses:

Ho : all the coefficients are equal zero, $b_2=b_3=b_4=...=b_k= 0$

Ha : at least one coefficient does not equal zero

Under the null Ho, the statistic $F = \frac{(SSR/(k-1))}{(SSE/(n-k))}$ follows an F-distribution with [(k-1),(n-k)] degrees of freedom whose critical value is given in the F-table where "n" is the number of observations and "k" is the number of unknown parameters. All were found to be significant at the 5% level of significance or greater. The significance of each coefficient is also tested by a traditional two tailed t-test.

Because a first regression is run using 1977 data and second regression run using 1982 data, it is interesting to test the equality of the two regression equations. Thus, a Chow test is conducted by running a pooled regression, with 94 observations. A change in regime in the regression is then tested via the following hypotheses :

Ho : $b_i(1977) = b_i(1982)$ for all i=1,...,k

Ha : at least one bi(1977) does not equal $b_i(1982)$

Again, under the null Ho, the statistic $F = \frac{(((SSEp-(SSE1+SSE2))/k)}{((SSE1+SSE2)/(n1+n2-2k)))}$ follows an F-distribution with [(k), (n1+n2-2k)] degrees of freedom. In this case, n1 = n2 = 47 observations.

Other tests of the data were undertaken to verify the regression estimates' properties of linearity, normality, unbiasedness, and BLUE. If these properties do not hold, obviously hypothesis tests are not valid with the usual statistics. The assumptions regarding homoskedasticity are examined with the Goldfeld-Quandt test (GQ) and the Breusch-Pagan test (BP). The assumptions necessary to use multiple linear regression appear to hold; in particular, heteroskedasticity and serial correlation are not detected.

Results

The results are organized as follows. Table 1 uses the top-4-firm concentration ratio throughout and table 2 uses the top-8-firm ratio as a measure of concentration.

Lines of the tables compare various specifications in terms of combinations of explanatory variables and of sample periods. Significance of the exogenous variable coefficients is assessed at each trial by examining values of t-tests and value of the adjusted-R^2.

Generally, the signs of the exogenous variables are positive for the constant (C), concentration ratio squared, ($CR4^2$), and advertising to sales (ADS), and negative for ADS squared (ADS^2) unless ADS is omitted from the equation. The coefficients are insignificant for KY and MES in all specifications. Three other points are particularly noticeable. First, the minimum efficient scale (MES) has a negative sign, and is not significant contrary to Rogers's model (Rogers, 1984). But, Pagoulatos and Sorenson (1983) also found a negative sign using 1972 data. The MES plant was approximated by the plant size with lowest labor costs. This method also uses Census data to determine which employment size class had the lowest labor costs as a percentage of sales. Value of shipment for that employment size class is divided by the number of establishments in the class to compute the average value of shipment per plant. But, Culberston and Morrison (1983) have shown that the midpoint-plant method, used in this paper, is more relevant because it more nearly agrees with economic-engineering studies. Second, the concentration ratio (CR4) which is generally positive is surprisingly negative in the 1977, 1982 and the pooled regression with the highest value of adjusted-R^2. Third, the square of this ratio ($CR4^2$) always has positive sign (except in the misspecified model which omits ADS). The final specification (last three rows) in table 1 appears to fit the data best as judged by the adjusted R^2. Therein, the positive but diminishing effects of advertising are apparent and the coefficients on CR4 and $CR4^2$ are nearly always significant.

The most significant exogenous variables of the model appear to be advertising expenditures, ADS squared, concentration, minimum efficient scale and capital intensity. In 1977, 1982 and the pooled regression, advertising expenditures and concentration are the most significant variables in explaining profit - as was found in previous studies. Again, the specification PROF = f (C, CR4, $CR4^2$, ADS, ADS^2) appears to fit the pooled data best as well.

The Chow test, conducted with this regression, yields the statistic

$$F = \frac{(((SSEp-(SSE1+SSE2))/k)}{((SSE1+SSE2)/(n1+n2-2k)))} = \frac{((6079.8-(3059.4 + 2776.7))/5}{(3059.4 + 2776.7)/(47+47-10))} = 0.70$$

which follows an F-distribution with [(5),(47+47-10)] degrees of freedom. The critical cutoff value is approximately 2.33 under this test. The pooled regression, with N = 94 observations, is therefore valid and reported in the table.

The regressions run with the top-8-firm concentration ratio (CR8) have lower fit than the regressions run with the top-4-firm concentration ratio (CR4). Moreover, the coefficients of top-8-firm concentration ratio (CR8) and of the square of (CR8) are not significant. In contrast, the coefficient of the square top-4-firm concentration ratio ($CR4^2$) is more highly significant.

Concluding comments

The hypothesis that concentration is positively related to market power is confirmed. The top-4-firm concentration ratio is more significant than the top-8-firm concentration ratio. Further, concentration and advertising are the most significant variables in explaining profit in the U.S. food industries in 1977 and 1982. The goal of advertising is to differentiate products in order to increase profits and apparently advertising has a positive but diminishing effect on profits. However, it should also be noted that the detection of correlation does not imply causality. Relationships between profits and concentration and advertising expenditures demonstrate the effects of market power. This fact helps to explain strategies employed by many U.S. food industries which desire to increase their market power by purchasing smaller companies and by increasing their market shares with large advertising expenditures. This conclusion is akin to Bresnahan's (1989), that there is "a great deal of market power, in the sense of price-cost margins, in some concentrated industries ... where pricing behavior may alternate between collusive monopolistic behavior and price wars in which a cartel temporarily collapses".

According to models from 1968 to 1982, concentration and advertising ratio-to-sales have become more and more significant. In contrast, variables such as minimum efficient scale (MES) and capital intensity (KY) are becoming less important. Technological change now also seems to be less of a determinant of profits. This hypothesis could be tested in the future with 1987 data. Comparisons could be made with food industries in the E.E.C. and in Japan, which may compete with the U.S. firms. The study of structure-performance relationships across various types of food industries would be insightful in explaining cross-sectional differences in this heterogeneous industry.

Table 1. Coefficients from profit equation, using the top-4-firm concentration ratio (CR4)[a]

Year	C	CR4	100 $(CR4)^2$	100GR	MES	KY	ADS	ADS^2	Adj. R^2 (%)	F-Test
1982	27.583 7.73**	-0.542 -1.65*	0.664 1.88*	-2.130 -0.32	-0.258 -0.82	-0.073 -0.57	14.61 5.52**	-1.635 -3.83**	59.71	10.74**
1977	16.20 4.70**	0.052 0.65				0.036 0.30	4.919 4.45**		37.84	10.34**
1982	18.69 4.99**	0.071 0.89				-0.120 -0.91	5.50 5.53**		48.78	15.60**
1977-1982	17.30 6.90**	0.064 1.16				-0.041 -0.46	5.251 7.24**		45.51	26.89**
1977	21.20 3.39**	-0.278 -0.94	0.358 1.15				9.808 3.77**	-1.025 -2.14**	42.76	9.59**
1982	25.66 4.23**	-0.528 -1.85**	0.601 2.04**				14.26 5.85**	-1.583 -3.96**	61.27	19.19**
1977-1982	23.06 5.34**	-0.382 -1.88*	0.458 2.17**				11.79 6.75**	-1.249 -4.17**	54.02	35.57**

[a] t-stats are given below coefficients
* denotes significance at 10% level
** denotes significance at 5% level

Table 2. Coefficients from profit equation, using the top-8-firm concentration ratio (CR8)[a]

Year	C	CR8	100 $(CR8)^2$	100GR	MES	KY	ADS	ADS^2	Adj. R^2 (%)	F-Test
1982	27.48	-0.355	0.287	0.080	0.060	-0.133	14.163	-1.40	55.68	9.26**
	2.52*	-0.95	0.92	0.01	0.21	0.13	5.21*	-3.35*		
1977	18.025	-0.0055				0.058	5.28		33.20	10.10**
	4.01**	-0.06				0.47	5.01**			
1982	20.31	0.019				-0.11	5.82		47.60	14.93**
	4.24**	0.26				-0.8	6.3**			
1977-1982	19.056	0.009				-0.24	5.59		44.55	25.90**
	6.11**	0.17				-0.26	8.21**			
1977	23.02	-0.253	0.217				10.307	-0.998	41.03	9.00**
	2.33*	-0.68	0.70				3.80	-2.00		
1982	27.70	-0.416	0.328				14.021	-1.383	57.69	16.68**
	2.91*	-1.18	1.14				5.57	-3.44		
1977-1982	24.51	-0.299	0.243				11.908	-1.131	51.56	28.75**
	3.66*	-1.20	1.18				6.61	-3.76		

[a] t-stats are given below coefficients
* denotes significance at 10% level
** denotes significance at 5% level

References

Bresnahan, T. F., "Industries with Market Power", in Handbook of industrial organization, eds. Schmalensee and Willig, Amsterdam, North-Holland, 1989 (1011-1057).

Bureau of the Census, Census of Manufactures: General summary, Washington, D.C.: U.S. Department of Commerce, 1977 and 1982.

Bureau of the Census, Census of Manufactures: Concentration Ratios in Manufacturing. Washington, D.C.: U.S. Department of Commerce, 1977, 1982.

Bureau of the Census, Census of Manufactures: Industrial Report series, 201 to 209, Washington, D.C.: U.S. Department of Commerce, 1977 and 1982.

Collins, N. and L. Preston. Concentration and Price-Cost Margins in Manufacturing Industries, Berkeley: University of California Press, 1968

Connor, J.M., R.T. Rogers, B.W. Marion, and W.F. Mueller, The Food Manufacturing Industries: Structure, Strategies, Performance and Policies, Lexington Books, 1985.

Culberston, J.D., and R.M. Morrison, Economies of Scale Data for the Food Manufacturing Industries, M. Sc. Washington, D.C. 1983.

Horst, T., At Home Abroad: A Study of the Domestic and Foreign Operations of the American Food-Processing Industry, Cambridge, Mass. Ballinger, 1974.

Pagoulatos, E., and R. Sorenson, "The Competitive Impact of Advertising in the U.S. Food Industries : A Simultaneous Equation Approach." Advertising and the Food System, Connor and Ward Editors, Madison, Wis.: NC-117, pp. 241-256, Sept. 1983.

Parker, R.C., and J.M. Connor, "Estimates of Consumer Loss Due to Monopoly in the U.S. Food-Manufacturing Industries", American Journal of Agricultural Economics, 61(1979): 626-639.

Rogers, R.T, A Structure-Price-Cost Margin Model Estimated over Time for Food and Tobacco Product Classes, 1954 to 1977, Working Paper 75, Madison, Wis, : NC-117, 1984.

Rogers, R,T,, and L,L, Mather, "Food Advertising, 1954 to 1979," Advertising and the Food System, Monograph 14, Connor and Ward Editors, Madison, Wis. : NC-117, pp. 75-94. Sept. 1983.