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THE RELATIONSHIP BETWEEN INDUSTRIAL SALES PRICES AND CONCENTRATION OF NATURAL GAS PIPELINES*

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1. Introduction.

Many economic studies find market concentration positively related to profits.[1] The findings may be explained either by oligopoly behavior or by greater efficiency of firms with large market shares. Although both explanations imply that concentration and profits will be positively related, they differ in their implications for the relationship between concentration and price. The oligopoly explanation is that increased concentration leads to less competition resulting in higher profits from higher prices [Weiss (1974, pp. 185-93)]. The efficiency explanation is that cost reductions lead to increased concentration and lower prices [McGee (1977, pp. 41-52, 75-9), Demsetz (1973), Peltzman (1977)]. This paper lends support to the oligopoly explanation by finding that market concentration is positively related to industrial sales prices of interstate natural gas pipelines.

One may think that American interstate natural gas pipelines provides a peculiar industry to look for a price-concentration relationship because interstate natural gas pipelines are regulated by the Federal Energy Regulatory Commission (FERC). But the prices of industrial sales of these pipelines are largely unregulated. Further, theoretical and anecdotal evidence suggests that competition does matter. Wellisz (1963) demonstrated that pipelines have an incentive

[1] These studies generally relate price-cost margins to concentration or some measure of rate of return to concentration. For a review of some of the results see Weiss (1974, pp. 201-31) and Kwoka (1985, pp. 931-7).

to expand capital above optimal levels and raise rates on off-peak service to the profit-maximizing level. MacAvoy and Noll (1973) provide evidence that the price elasticity of demands for pipelines' industrial customers are greater than the market price elasticity of demand for industrial customers. Their result implies that inter-pipeline rivalry increases the elasticity of demand for individual pipelines. This anecdotal evidence suggests that competition may be an important factor in natural gas pricing to industrial customers.

Interstate natural gas pipelines also provide an interesting industry to study because FERC is increasingly relying on market forces to determine the pricing of natural gas and related services. For example, a recent Notice of Proposed Rulemaking (1988) would allow the brokering (reselling) of transportation capacity at unregulated prices in markets that are "workably competitive." Thus, determining the significance of competition in the industry can help guide policy makers as they place greater emphasis on market forces as a regulatory tool.

The remainder of this paper is outlined as follows. Section 2 presents a model of oligopoly behavior and presents three empirical propositions developed from the model. Section 3 outlines the method of verifying the propositions. Section 4 presents the results which are consistent with the propositions and support the position that increased concentration leads to higher prices. Section 5 presents conclusions and provides some implications of the findings.

2. The effect of changing the number of sellers in a market.

Assume that the firms in a market desire to maximize profits from their sales in the market. The profits of each firm can be represented by:

$$(1) \qquad \pi_i = p\left(\sum_{j=1}^{n} x_j\right)\cdot x_i - c_i(x_i)$$

where π_i represents the profits of firm i; $p(\cdot)$, the market price, is a function of the total quantity of x sold in the market; x_i is the quantity sold by firm i; $c_i(x_i)$ are firm i's costs; and n is the number of firms selling in the market. Each firm chooses x_i to maximize equation (1). The first order condition for profit maximization is:

$$(2) \qquad \frac{\partial \pi_i}{\partial x} = p\left(\sum_{j=1}^{n} x_j\right) + x_i\cdot p'\left(\sum_{j=1}^{n} x_j\right)\cdot(1+\alpha_i) - c_i'(x_i) = 0$$

where α_i is the firm i's conjectural variation ($\alpha_i = \Sigma\partial x_j/\partial x_i$, $j \neq i$). Summing (2) over n firms gives

$$(3) \qquad n\cdot p(X) + X\cdot p'(X)\cdot(1+\alpha) - \sum_{i=1}^{n} c_i'(x_i) = 0$$

where X is total market output ($X = \Sigma x_i$) and α is a weighted average of the α_i's. Equation (3) determines the industry level of output given the number of competitors, competitive interactions, market demand parameters, and firm cost parameters.

Additional assumptions make the discussion easier to follow. First, assume that the firms exhibit Cournot behavior ($\alpha_i = \alpha = 0$). The

Cournot assumption does not affect the qualitative results of the model as long as α does not change dramatically with a change in the number of competitors (for example, a firm enters and breaks up a cartel). Second, assume that the (inverse) demand curve is linear and let it be represented by $p(X) = a - b \cdot X$. Third, assume that the marginal costs of each firm are constant (i.e., $c_i'(x_i)=c_i$).

Given these assumptions, the market price is given by:

$$(4) \qquad p = \frac{a + \sum_{i=1}^{n} c_i}{n + 1}$$

Therefore, the market price is a function the demand curve intercept (a); the vector of marginal costs (c_1 ..., c_n); and the number of firms (n). Or, $p = p(a;c_1,\cdots,c_n;n)$. From (4) three propositions result.

Proposition 1: Price decreases as the number of firms supplying the market increase.

The change in price from increasing the number of firms by 1 is given by:

$$(5) \qquad \frac{\Delta p}{\Delta n} = p(n+1) - p(n)$$

$$= \frac{c_{n+1} - p(n)}{n+2}$$

A profit maximizing firm would not enter the market if its marginal costs were higher than the market price. Therefore, from (5) $\Delta p/\Delta n < 0$ and price decreases as the number of firms increases.

Proposition 2: Price increases as the marginal cost of firm i increases.

A change in price given a change in a firm's cost is

$$\frac{\Delta p}{\Delta c_i} = \frac{1}{n + 1} > 0 \tag{6}$$

which is positive establishing proposition 2.

Proposition 3: The increase in price given an increase in firm i's cost decreases as the number of firms increases.

Proposition 3 states that the effect described in proposition 2 decreases as the number of firms increases. The change in equation (6) as n increases by one is given by:

$$\frac{\Delta^2 p}{\Delta c_i \Delta n} = \frac{1}{(n+1)+1} - \frac{1}{n+1} = \frac{-1}{(n+2)\cdot(n+1)} < 0 \tag{7}$$

Therefore proposition 3 is established.

Propositions 1 and 2 are well known. The intuition behind proposition 1 is that as the number of firms supplying a market increase, the market power of any one firm decreases. As long as the firms do not cooperate, the decrease in each firm's market power results in a decrease in the market price. The intuition of proposition 2 is that as the costs of a firm increase, the firm becomes a less effective competitor. As a result, the market power of the other firms increase and price increases. Proposition 3 is less well known but also results from this and similar models of oligopoly. Intuitive reasoning suggests that as the number of firms increases, the competitive significance of any one firm decreases. Thus, the competitive effects from a change in a single firm's costs have less effect on price.

3. Data and estimation technique.

Observations from the 22 interstate natural gas pipelines listed in table 1 are used to empirically investigate the propositions. The pipelines are those interstate pipelines that reported industrial sales between January 1984 and December 1986 on FERC Form 11 and also were included in Gallick's (1988) study of concentration of natural gas pipelines. Pipelines with fewer than 36 observations either did not report industrial sales over the entire sample period or reported nonpositive values for industrial sales volume or revenues.

Table 2 presents summary statistics for the data. AR, the monthly average revenue from industrial sales, serves as a measure of the average price that a pipeline receives. Most pipelines sell gas in many different markets. For example, Transcontinental Gas Pipe Line markets gas in at least 15 metropolitan statistical areas (MSAs) along its way from the Gulf of Mexico to New York City. AR, therefore, is the weighted average price from sales in more than one market. The averaging over markets makes finding a relationship between prices and the number of sellers less likely. The pipelines, however, sell in different sets of markets and on average face different numbers of competitors. Thus, AR is expected to provide a useful measure of price.

ACOST, the monthly average cost of purchased gas, provides a measure of the marginal cost of supplying an industrial customer. The average cost of gas determines the marginal cost of a pipeline selling gas to an industrial customer because of FERC regulations. The regulations roll the gas costs of serving industrial customers into the gas costs for the sales-for-resale customers. Therefore, a pipeline's average cost of gas for all customers sets the marginal cost of serving industrial customers.[2] In the sample, the average cost of gas accounts for 80 percent of the average price.

To relate a pipeline's average revenue to the number of competitors in a pipeline's markets, the number of competitors must be averaged over the different markets because the price and costs data are averaged over markets. Gallick (1988) reports the sales of interstate pipelines in 208 MSAs in 1983. Making the assumption that industrial sales are proportional to total sales, the weighted average number of competitors in pipeline i's markets is

$$(8) \qquad N_i = \sum_{j=1}^{n} \sigma_{ij} n_j$$

where σ_{ij} is the share of pipeline i's industrial sales that occur in market j and n_j is the number of interstate pipelines making sales in market j.

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[2] Other variables that might effect marginal costs--such as the pipeline's length, total throughput, and industrial sales share of total throughput--were added to the estimated equations but did not affect the tests of the three propositions. The estimations presented in section 4 do not include these other variables.

Three other measures of market participants are also used. First, NHHI is the weighted average Herfindahl-Hirschman index (HHI) based on the number of interstate pipelines making sales in each of the markets ($HHI_j = 1/n_j$). This variable uses the same information as N but weights the number of competitors differently. N weights the competitive impact of adding a fourth pipeline to a market with three incumbent pipelines the same as the competitive impact of adding a second pipeline in a market that is currently a monopoly. NHHI discounts the impact of additional competitors: a fourth pipeline in a market would have about 16 percent of the impact as the second pipeline. Second, NA is the weighted average number of independent pipelines located within each MSA. In addition to interstate pipelines making sales within the MSA, NA includes pipelines that pass through the MSA but do not make sales as well as intrastate pipelines making sales within the MSA. Third, NAHHI is the weighted average HHI measure based on the number of competitors measured by NA.

The statistical model used to empirically examine the propositions is:

$$AR_{it} = \beta_0 + \beta_1 N_i + \beta_2 ACOST_{it} + \beta_3 (ACOST_{it} \cdot N_i) + e_{it} \tag{9}$$

The propositions are cross-sectional; therefore F tests were performed to determine if pooling over the 36 time periods was appropriate. The tests did not reject the hypothesis that the coefficients were constant over time; therefore, the results reported in section 4 are from the pooled sample.[3]

If proposition 1 is correct, then average revenue is expected to be negatively related to the average number of pipelines in an individual pipeline's market. This is tested by determining if β_1 plus β_3 times ACOST evaluated at its sample means is less than zero ($\beta_1+\beta_3\cdot ACOST<0$). Proposition 2 implies that average revenue increases as a pipeline's average costs increase. This is tested by determining if β_1 plus β_3 times N evaluated at its sample mean is greater than zero ($\beta_1+\beta_3\cdot N>0$). Proposition 3 implies that the increase in average revenue from a cost increase decreases as the average number of pipelines in an individual pipeline's markets increases. This is tested by determining if β_3 is less than zero ($\beta_3<0$). When NA is used to estimate equation (9) instead of N, the proposed tests do not change. When NHHI and NAHHI are used, the tests of proposition 1 and proposition 2 reverse in sign because NHHI and NAHHI are inversely related to N and NA.

4. Empirical results.

The results of estimating equation (9) using the four different measures of concentration are presented in table 3. Column 1 presents the results of using the weighted average of the number of interstate pipelines making sales in each market (N) as the measure of the number

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[3] The stability of the coefficient estimates over time also indicates that the various regulatory changes during the sample period did not signficantly effect competition for pipeline sales of gas to industrial customers.

of competitors. The coefficient on ACOST·N is negative and statistically less than at the 1 percent confidence level. This result is consistent with proposition 3 that as the number of competitors increases, the increase in price from higher firm costs decreases. The tests of propositions 1 and 2 are presented at the bottom of the column. Both figures have the expected sign and are significant at a 1 percent confidence level. The results indicate that price on average decreases $0.60 per thousand cubic feet of gas (mcf), about 15 percent, as the average number of competitors increases by 1. Further, a pipeline's price on average increases by only $0.55/mcf as a pipeline's gas cost increases by $1.00/mcf, indicating that pipelines do not fully pass through cost increases.

The second column presents the results of using NHHI as the measure of the number of competitors. Recall that NHHI is the weighted average of the reciprocal of the number of competitors in each market. Thus, NHHI is negatively related to N and the predicted signs of propositions 1 and 3 become positive. The results reported in column 2 are consistent with the modified hypotheses. The coefficient on ACOST·NHHI is positive and statistically significant at the 1 percent level, confirming proposition 3. As expected, the test of proposition 2 is similar to that reported in column 1 and the test of proposition 1 is significantly greater than zero. The estimation implies that on average a second pipeline in a market lowers prices by $1.08/mcf, a third pipeline lowers prices by $0.36/mcf, and a fourth by $0.18/mcf.

Columns 3 and 4 present the counter parts of columns 1 and 2 using the number of all independent pipelines in the markets rather than just the number of interstate pipelines making sales in the markets. The results are similar to those reported in columns 1 and 2. Price decreases as the number of competitors increase, price increases as costs increase, and an individual pipeline's effect on price from a cost change decreases as the number of competitors increase. The main difference is that the R^2 shows a slight improvement when considering all potential competitors. Regardless of whether the number of interstate pipelines making sales or all pipelines are used, use of the HHI measures rather than the simple numbers does not significantly affect the explanatory power of the equations.

5. Conclusions.

This paper explores the relationship between concentration and prices. Section 2 presents a theoretical model in which price falls as the number of competitors increases. The model also implies that price increases as an individual firm's costs increase, but this cost effect on price declines as the number of competitors increases. Section 4 then presents results consistent with the implications of the theory. In a sample of the industrial sales of 22 interstate natural gas pipelines, prices on average are inversely related to the average number of competitors that a pipeline faces. The results also indicate that an individual pipeline's effect on price from a change in costs declines as the number of competitors increases. Based on the consistency of the theoretical and empirical results, concentration as measured by the number of competitors in a market is a significant determinant of the price of natural gas sold to industrial customers.

This finding is consistent with a number of other studies of the price-concentration relationship [Bell and Murphy (1969), Marvel (1978), Lamm (1981)].

The empirical results have policy implications for at least two U.S. government agencies influencing American natural gas markets. First, the Federal Trade Commission has intervened in several acquisitions involving natural gas pipelines.[4] This research suggests that intervening to prevent increases in concentration in the natural gas industry may benefit industrial customers. The positive price-concentration relationship indicates that natural gas is a relevant product for antitrust scrutiny and that increases in concentration may result in higher prices.

Second, FERC has been undertaking a more market oriented approach to its regulations. The empirical results presented suggest that competition may be as effective as regulation at controlling price. For example, the average price to industrial customers in the sample is \$4.03/mcf. The corresponding average price in regulated transactions (excluding sales to major pipelines) is \$3.78/mcf. The average number of competitors is 2.12; therefore the estimates of $\Delta p/\Delta n$ from table 3 imply that on average three pipelines serving a market would be as an effective check on price as is government price regulation.

The results also have broader implications because they indicate that in highly concentrated markets prices tend to increase as the number of competitors in markets decrease. Therefore, preventative

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[4] See, for example, MidCon Corp., 107 F.T.C. 48 (1986) and InterNorth, Inc., et al., 106 F.T.C. 312 (1985)

merger policy in such markets may be justified in highly concentrated markets (HHI above 2500). The applicability of this price-concentration relationship, however, is not universal to all concentrated markets. Federal and state regulations provide formidable entry restriction to new competition for American interstate natural gas pipelines. Difficult entry conditions should be a prerequisite to apply these results to other concentrated markets.

The results may also have implications outside of North America. The European gas industry is much more concentrated that the gas industry in North America. Some European gas executives feel that "[d]ifferences in the way the gas market is organized in Europe and in North America are such that we Europeans would no doubt be making a grave mistake if we attempted to use solutions currently prevailing in the U.S. and Canada to deal with the situation on our continent."[5] But the results presented here indicate that policies to increase competition may be as effective as policies designed to simply regulate the current market structure. Europe, too, may benefit from greater competition in its gas industry.

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[5] Jacques Fournier, Chairman of Gaz de France, Oil & Gas Journal, June 20, 1988, p. 18.

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Table I

Interstate pipelines used in estimations

Pipeline company	Number of observations
Arkla, Inc.	24
Colorado Interstate Gas Co.	36
Consolidated Gas Transmission Corp	36
East Tennessee Natural Gas Co.	36
El Paso Natural Gas Co.	34
Ensearch Corp	24
Florida Gas Transmission Co.	36
K-N Energy, Inc.	36
Mississippi River Transmission Corp	36
Mountain Fuel Resources, Inc.	6
Natural Gas Pipeline Co.	33
Northern Natural Gas Co.	36
Northwest Central Pipeline Co.	36
Northwest Pipeline Corp	35
Panhandle Eastern Pipeline Co.	36
Southern Natural Gas Co.	36
Tennessee Gas Transmission Co.	36
Texas Gas Transmission Corp	35
Transcontinental Gas Pipe Line Corp	35
Transwestern Pipeline Co.	36
Trunkline Gas Co.	36
United Gas Pipeline Co.	36

Table II

Variables used in the regressions

Variable	Observa-tions	Mean	Standard Deviation	Minimum Value	Maximum Value
AR	730	4.030	1.425	1.000	13.190
ACOST	730	2.860	0.612	0.671	6.482
N	730	2.120	0.846	1.000	4.084
NHHI	730	0.631	0.205	0.292	1.000
NA	730	2.922	1.162	1.000	4.992
NAHHI	730	0.477	0.209	0.250	1.000

Table III

Regression results for industrial sales

Variable	(1)	(2)	(3)	(4)
Constant	-1.600 (2.66)	2.66 (3.96)	2.042 (3.47)	2.475 (4.82)
N	0.379 (1.56)			
NHHI		-0.530 (0.50)		
NA			0.071 (0.40)	
NAHHI				-1.205 (1.21)
ACOST	1.28 (5.90)	-0.004 (0.016)	1.188 (5.66)	0.091 (0.51)
ACOST·N	-0.345 (3.73)			
ACOST·NHHI		0.940 (2.50)		
ACOST·NA			-0.195 (3.04)	
ACOST·NAHHI				1.377 (3.89)
R^2	0.18	0.17	0.23	0.24
Observations	730	730	730	730
Proposition 1	-0.608 (9.39)	2.158 (8.93)	-0.487 (11.60)	2.733 (12.18)
Proposition 2	0.549 (6.93)	0.593 (7.40)	0.618 (8.26)	0.566 (9.91)

Note: Absolute value of t-statistics are given in parentheses.