Measuring Oligopsony and Oligopoly Power in the U.S. Paper Industry

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Abstract: The U.S. paper industry has been increasingly concentrated ever since the 1950s. Such an industry structure may be suspected of imperfect competition. This study applied the new empirical industrial organization (NEIO) approach to examine the market power in the U.S. paper industry. The econometric analysis consisted of the identification and estimation of a system of equations including a production function, market demand and supply functions, and two conjectural elasticities indicating the industry's oligopsony and oligopoly power. By employing annual data from 1955 to 2003, the above system of equations was estimated by Generalized Method of Moments (GMM) procedure. The analysis indicated the presence of oligopsony power but no evidence of oligopoly power over the sample period.

Keywords: Conjectural elasticity; GMM; Market power; NEIO

Introduction

The paper sector (NAICS 32-SIC 26) has been the largest among the lumber, furniture, and paper sectors in the U.S. forest products industry. According to the latest Annual Survey of Manufacturing in 2005, the value of shipments for paper manufacturing reached $163 billion or a 45% share of the total forest products output (U.S. Bureau of Census, 2005). Thus, the paper sector has played a vital role in the U.S. forest products industry.

However, spatial factors such as the cost of transporting products between sellers and buyers can mitigate the forces necessary to support perfect competition (Murray, 1995a). This is particularly true in markets for agricultural and forest products. For example, timber and logs are bulky and land-intensive in nature, thus leading to high logging service fees. In fact, the share of harvesting margin, which is defined as the difference between the delivered log price and the stumpage price over the delivered log price, has been as high as around 60% in Mississippi for the last 30 years (Guo et al., March 2007). In addition, the high concentration in the paper industry has also aroused concern about its market power. In 2002, the CR4, as measured by the share of value of shipments accounted by the largest four companies in the industry, has reached 49% (U.S. Bureau of Census, 2006), and actually the CR4 for the U.S paper industry has been ever increasing since 1954 from around 18% (Economic Census, various years). Such a structurally asymmetric industry, i.e., relative few timber processors in contrast to a large number of forest landowners and paper products consumers, may result in imperfect competition in both the pulpwood input market and the paper products output market. This situation has even been aggravated by those huge mergers and acquisitions (M&As) in recent

decades. Therefore, both oligopsony and oligopoly power can be suspected in the U.S paper industry.

By employing annual data from 1955 to 2003, this study examined the market power in both the pulpwood input and paper products output markets in the U.S. paper industry simultaneously. Results from this study will be helpful in understanding the market behavior of the U.S. paper industry.

Background and Previous Studies

Market power possessed by industrial firms has been an issue of great interest in the past years. Geroski (1988), Bresnahan (1989), Kadiyali, et al. (2001) and Digal and Ahmadi-Esfahani (2002) provided excellent reviews of empirical approaches in the market power literature. Overall, there have been two major methods, i.e., the structure-conduct-performance paradigm (SCPP) approach and the new empirical industrial organization (NEIO) approach. Prior to 1980's, the dominant approach was the SCPP. Based on the assumption that the level of competition could be implied by an industry's structural features, the SCPP approach tried to establish a direct link from industry structure to conduct. Yet, the SCPP approach was criticized later because the relationship between industry structure and conducts was not unambiguously predicted by the theory of imperfect competition, and high concentration in an industry did not necessarily imply noncompetitive behavior (Ronnila and Toppinen, 2000).

To study the existence of market power more rigorously, researchers have gradually turned to the NEIO approach. One prominent component of the NEIO approach is to estimate the conjectural elasticities, also defined as market conduct parameters. The conjectural elasticities measure the overall market reaction to an individual firm's change in input demand and output supply. A review of the NEIO studies revealed that most of the attention in the NEIO literature has been paid to the imperfect competition in either the input or output market. Research that considered both markets simultaneously has been limited. The exceptions are those several studies in the U.S. food processing industry (Schroeter, 1988; Azzam and Pagoulatos, 1990; Wann and Sexton, 1992; Alston et al., 1997; Sexton, 2000). Models that only examined oligopsony or oligopoly power ran the risk of understating the extent of the market power distortion or erroneously attributing distortions to the wrong form of market power (Sexton, 2000).

For the forest products industry, market power research and the application of NEIO approach have been quite limited. Most of these studies were conducted in Canada, Finland, Norway, and Sweden. Bernstein (1992) found competitive behavior in both the input and output markets in the Canadian sawmill and paper industries after accounting for capital adjustment costs. Ronnila and Toppinen (2000) applied duality to derive the factor demand system, and the static estimation showed that the pulpwood market in Finland had been competitive during the period 1965-1994. Based on data covering individual Norwegian sawmills over the period 1974-1991, Stordal and Baardsen (2002) tested for price-taking behavior incorporating cross-sectional effects and inter-temporal effects, and market power was found for certain years. Bergman and Brannlund (1995) tested the market power for the Swedish pulpwood market. The estimates of strongly time-varying conjectural elasticities indicated an unstable cartel situation. Bergman and

Nilsson (1999) found only weak evidence of market power for the Swedish pulp and paper industry by a conjectural elasticity model using industry data for the 1970-1993 period.

Several studies were conducted for the forest products industry in the United States. Murray (1995b) studied oligopsony power in both the U.S. pulpwood and sawlog markets. He modeled the wood as a quasi-fixed factor so the shadow prices of the wood input could be estimated from a flexible-form profit function. To explore the time-varying market power indices, a polynomial function of fuel cost and average mill capacity was established. His results suggested that the U.S. pulpwood market was more oligopsonistic than the sawlog market. Asinas (2001) tested market power of the U.S. paper and lumber industries and his findings were consistent with Murray's except the magnitudes of market power exertion. Based on the single-equation analysis, Yerger (1996) examined the market power in the U.S. pulp export market. While imperfect competition was found in chemical pulp export market, there was no clear support for either perfect competition or the presence of market power in the U.S. sulphate pulp export market.

Given the fact that empirical research dealing with the market power in the U.S. paper industry is still sparse, there is great need to examine its industrial organization, especially after the frequent restructuring activities in the form of mergers and acquisitions in recent decades.

Theoretical Framework

Consider the U.S. paper industry in which N firms produce a homogenous output (Q) using inputs of pulpwood (x_1), labor (x_2), capital (x_3), and non-wood materials (x_4) with price w_1, w_2, w_3, w_4. Suppose each firm has some market power in procuring the pulpwood input and in selling its paper products output, but is a price taker for other inputs. Furthermore, assume each firm is profit-maximizing so the optimum for firm j ($j = 1, 2, \dots, N$) is to choose x_{kj} ($k = 1, 2, 3, 4$) that maximizes its profits.

In practice, absence of price and quantity data on the firm level input and output generally results in considering the problem at the industry level. Nevertheless, an additional assumption must be presumed , that is, in equilibrium, the conjectural elasticities are invariant across firms (Appelbaum, 1982), i.e., $\theta_1 = \theta_2 = \dots = \theta_N = \theta$, and $\varphi_1 = \varphi_2 = \dots = \varphi_N = \varphi$.

Based on the above assumptions, the NEIO approach could be explained as follows. Let the jth firm's production function be defined by

(1) $q_j = f(x_{1j}, x_{2j}, x_{3j}, x_{4j})$

where q_j is the output produced (paper products). Let the inverse market demand curve facing the industry in its output market be given by

(2) $P = g(Q)$

where P is the market price for paper products and $Q = \sum_{j=1}^{N} q_j$ is the total industry output. The inverse market supply function for the pulpwood input is given by

(3) $w_1 = h(X_1)$

where w_1 is the market price for pulpwood input and $X_1 = \sum_{j=1}^{N} x_{1j}$ is total industry pulpwood input. Thus, the jth firm's profit could be calculated as

(4) $\Pi_j = Pq_j - \sum_{k=1}^{4} w_k x_{kj}$ $j = 1, 2, \ldots, N$

subject to (2) and (3). The fist order conditions corresponding to this profit maximization problem are given by:

(5) $\dfrac{w_1}{P} = (1 + \dfrac{\theta_j}{\eta}) f_{x_{1j}} - \dfrac{w_1}{P} \dfrac{\varphi_j}{\varepsilon}$

(6) $\dfrac{w_k}{P} = (1 + \dfrac{\theta_j}{\eta}) f_{x_{kj}}$, $k = 2, 3, 4$

where $\eta = \partial Q \times P / (\partial P \times Q)$ is the price elasticity of the output demand;
        $\varepsilon = \partial X_1 \times w_1 / (\partial w_1 \times X_1)$ is the market price elasticity of the pulpwood input supply;
        $\theta_j = \partial Q \times q_j / (\partial q_j \times Q)$ is the jth firm's conjectural elasticity in the output market;
        $\varphi_j = \partial X_1 \times x_{1j} / (\partial x_{1j} \times X_1)$ is the jth firm's conjectural elasticity in pulpwood input market;
and
        $f_{x_{kj}} = \partial q_j / \partial x_{kj}$ is the marginal product of the kth input used by firm j.

In theory, the conjectural elasticities, θ_j and φ_j, provide benchmarks in testing for price-taking behavior or degree of competitiveness (Appelbaum, 1982). $\theta_j \in [0, 1]$ measures departures from competition in selling the output. $\theta_j = 0$ denotes perfect competition; $\theta_j = 1$ denotes pure monopoly; other values denote various degrees of oligopoly power with higher values of θ_j denoting greater departures from competition. φ_j plays a similar role in terms of procurement of the pulpwood input, denoting possible perfect competition, monopsony, and various degrees of oligopsony power. In this study, the null hypothesis was that the conjectural elasticities equal zero. Rejecting the null hypothesis would suggest that the U.S. paper industry has market power on either the factor market, or the products market, or both.

Assuming identical conjectural elasticities across firms, the aggregate analogue of the optimality conditions, (5) and (6) can be written as:

(7) $\dfrac{w_1}{P} = (1 + \dfrac{\theta}{\eta}) f_{x_1} - \dfrac{w_1}{P} \dfrac{\varphi}{\varepsilon}$

(8) $\dfrac{w_k}{P} = (1 + \dfrac{\theta}{\eta}) f_{x_k}$, $k = 2, 3, 4.$

Econometric Model

In order to estimate the model previously described, specifications of the functional forms are needed. Selecting a functional form for the production function will lead to a group of empirical equations. Without imposing severe constraints on the production function, one form generally adopted is the transcendental logarithmic (translog) production function (Christensen et al., 1971):

$$(9) \quad \ln Q = \beta_0 + \sum_{k=1}^{4} \beta_k \ln X_k + 1/2 \sum_{k=1}^{4} \sum_{i=1}^{4} \beta_{ki} \ln X_k \ln X_i.$$

From the above equation, the marginal product for the kth input is

$$(10) \quad f_{x_k} = (\beta_k + \sum_{i=1}^{4} \beta_{ki} \ln X_i) \frac{Q}{X_k}, \qquad k = 1, 2, 3, 4.$$

Substituting Eq. (10) into Eq. (7) and (8) leads to the following share equations

$$(11) \quad S_1 = \frac{1 + \theta/\eta}{1 + \varphi/\varepsilon} (\beta_1 + \sum_{i=1}^{4} \beta_{1i} \ln X_i)$$

$$(12) \quad S_k = (1 + \theta/\eta)(\beta_k + \sum_{i=1}^{4} \beta_{ki} \ln X_i), \qquad k = 2, 3, 4$$

where $\beta_{ik} = \beta_{ki}$, and $S_k = w_k X_k /(PQ)$ is the share equation for the kth input ($k = 1, 2, 3, 4$).

In total, Eq. (9), (11), and (12) formed a system of five equations. The system of equations could be estimated by the Generalized Method of Moments (GMM) procedure using time series data from 1955 to 2003. GMM, as a non-linear estimator, allows the use of instrumental variables to solve the possible endogeneity problem (Asinas, 2001). The instrumental variables used in the estimation included the price for each of the four inputs, the average mill capacity, per capita disposable income, the production index for manufacturing, CR4 in the U.S. paper industry, and a time trend. Furthermore, as exogenous point estimates of the market price-elasticities, -0.4 and 0.3 were used for η and ε, respectively (Newman, 1987; Newman and Wear, 1993; Zhang and Buongiorno, 1997; Sun, 2006).

Data

Table 1 listed the definition and data sources of the variables used in this study. Annul data for the U.S. paper mills and paperboard mills (NAICS 32212 and 32213-SIC 2621 and 2631) were constructed from 1955 to 2003. The pulp mills (NAICS 32211-SIC 2611) was excluded for two reasons: one is that the output from the pulp mills is an intermediate input in paper

Table 1. Variable definition and data sources

Variables	Definition and data sources
Value of industry output (PQ)	Industry value of shipments plus the change in inventory from CM and ASM, various years. Missing data were filed by interpolation.
Quantity of paper and board output (Q)	Output data in thousand short tons for 1965-2002 were taken from Howard (2003). The data for the rest of years were supplemented by Agricultural Statistics.
Quantity of wood input (x_1)	Includes softwood and hardwood roundwood and chips/residues in thousand cords. Data for 1965-2002 were from Howard (2003). Data for 1955-1964 and 2003 were supplemented by Adams, et al. (2006) and Agricultural Statistics, respectively.
Wood input price (w_1)	Weighted average price. Delivered price of softwood pulpwood, hardwood pulpwood, and pulp chips were from Timber Mart-South (Norris, 1977-2001) and Adams, et al (1988). The weights were the volume of each components from Howard (2003).
Wood input value	Quantity times price of wood input.
Labor cost	Total compensation as reported in CM and ASM.
Labor quantity (x_2)	The sum of annual production hours and non-production workers (all employees minus production workers) times 2,000 hours per worker. All these data were from CM and ASM.
Labor wage (w_2)	Hourly earnings computed as labor cost divided by labor quantity.
Capital cost	The sum of interest, depreciation, depletion and tax expenses as reported in CSBSI (Gollop and Roberts, 1979).
Capital quantity (x_3)	The sum of net depreciable and depletable assets, land and inventories as reported in CSBSI (Gollop and Roberts, 1979).
Capital price (w_3)	Capital cost divided by capital quantity.
Non-wood materials cost	Computed as the total cost of materials recorded in the CM/ASM series less the cost of wood input.
Price of non-wood materials (w_4)	The price index of intermediate inputs in manufacturing published in Statistics Abstracts, various issues.
Quantity of non-wood materials (x_4)	Cost divided by price of non-wood materials.
Average mill capacity	Total production divided by total establishments. Establishment data were reported only in census year in CM. For non-census year, figures were filed by interpolation.
Per capita disposable income	Published annually by the U.S. Department of Commerce, Bureau of Economic Analysis.
Production index for manufacturing	From the Federal Reserve Statistical Release, Board of Governors of the U.S. Federal Reserve System.
CR4	Only reported in CM in census year. For non-census year, figures were filed by interpolation.
Time trend	Defined as the calendar year minus 1954.

manufacturing so combining this sector overestimates the total industry output; the other is that most woodpulp is produced and transferred within establishments in the paper and paperboard sectors (Murray, 1995b). The data were collected mainly from the following sources: Census of Manufacturing (CM), Annual Survey of Manufacturing (ASM) for total value of output, labor, and total cost of materials; Corporation Source Book of Statistics of Income (CSBSI) for capital input; and USDA Forest Service and Timber Mart-South for pulpwood input.

The value of the capital input and capital cost were calculated following the procedure outlined in Gollop and Roberts (1979). A two year average was taken since the Internal Revenue Service (IRS) data is based on fiscal year definition (i.e., from July to June) against calendar year. For the total establishment data, information from Statistics of U.S. Businesses was also incorporated for the most recent years (1997-2003).

For pulpwood input price data volume weighted average price of delivered softwood pulpwood, hardwood pulpwood, and chips and residues was constructed and used as an approximation. The delivered price data were obtained from Timber Mart-South since there is no such nation wide price index. Delivered southern pine price was chosen as a proxy for mixed softwood pulpwood.

Empirical Results

The estimation results by the Generalized Method of Moments were reported in Table 2. The model fitted well according to the adjusted R^2 values and t-statistics. The highest adjusted R^2 was 0.973 for the production equation, and the lowest was 0.205 for the share equation for the non-wood materials. By t-statistics, 11 of the 15 parameter estimates were significant at the 5% level or better, and most of them were of the expected sign.

For the key parameters of conjectural elasticities, the estimate for the pulpwood input market was 0.253 and significant at the 5% level. The estimate of conjectural elasticity for the paper products output market fell out of the range of [0, 1], but not significant. This implied the existence of significant oligopsony power in the pulpwood input market but no evidence of oligopoly power in the paper products output market.

In summary, the null hypotheses of price-taking conduct in the pulpwood input market was rejected. The U.S. paper industry tended to exert oligopsony power in the past several decades. Nevertheless, there was no indication of exertion of oligopoly power from the estimation results.

Conclusions and Limitations

Ever since the 1950s, the U.S. paper industry has been increasingly concentrated. Recent mergers and acquisitions within the industry have even aggravated this situation. Suspecting the implicit market power in such an industry structure, this study examined the oligopsony and oligopoly power simultaneously in both the pulpwood input market and the paper products output market in the U.S. paper industry. The econometric analysis consisted of the identification and estimation of a system of equations including a production function, market demand and supply functions, and two conjectural elasticities indicating the industry's

oligopsony and oligopoly power. GMM method was employed and annual data from 1955 to 2003 were used in the estimation.

Table 2. Estimates of the Parameters and Conjectural Elasticities for the U.S. paper industry by the Generalized Method of Moments

Parameter	Estimate	t-Statistic	p-Value
β_0	6.713	3.800	0.000
β_1	-0.544	-1.467	0.144
β_2	0.375	4.034	0.000
β_3	0.035	0.360	0.719
β_4	1.186	3.430	0.001
β_{11}	0.157	4.466	0.000
β_{12}	-0.044	-2.304	0.022
β_{13}	-0.002	-0.220	0.826
β_{14}	-0.152	-5.370	0.000
β_{22}	0.051	3.764	0.000
β_{23}	-0.023	-3.837	0.000
β_{24}	0.048	1.618	0.107
β_{33}	0.056	7.762	0.000
β_{34}	-0.061	-3.315	0.001
β_{44}	0.253	5.083	0.000
Conjectural elasticity			
Output market θ	-0.004	-0.402	0.688
Input market φ	0.234	2.475	0.014
Model performance			
Equation	Adj. R^2	Durbin-Watson	
$\ln Q$	0.973	0.537	
S_1	0.584	0.173	
S_2	0.554	1.186	
S_3	0.813	0.517	
S_4	0.205	0.718	

The empirical results revealed the presence of oligopsony power in the pulpwood input market but no evidence of oligopoly power in the paper products output markets in the past several decades. The exertion of market power in the U.S. paper industry implied an inefficient market, in which consumer and producer surpluses would be reduced, and deadweight losses would be created to the society.

It should be noted that although the NEIO approach can detect the degree of market power, but it is limited in identifying its sources (Bresnahan, 1989). The oligopsony power of the paper industry in the wood input market has been long associated with the high costs of transporting the bulky raw wood materials (Murray, 1995b). Additionally, rigorous environmental regulations have also been postulated as factors in creating barriers to entry and increasing the potential market power in the U.S. paper industry (Gomez, 1997). Finally, the overall exertion

of oligopsony power in the last several decades may be associated with a number of market forces and shocks, among which are oil shocks, and economic cycles (Asinas, 2001).

Overall, this study extended the literature in examining the market power in both the input and the output markets in the U.S. forest products industry. At the same time, given the existence of market power in the U.S. paper industry, this study brings up several interesting questions. Future research can examine what factors determine the market power, how the market power changes over time, and how market power influences the welfare of both the forest landowners and paper products retailers.

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