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Assessing Time-Varying Oligopoly and Oligopsony Power in the U.S. Paper Industry

Bin Mei and Changyou Sun

The U.S. paper industry has become increasingly concentrated and therefore been suspected of imperfect competition. In this study, the new empirical industrial organization approach is employed to measure the degree of oligopoly and oligopsony power in the U.S. paper industry simultaneously. The model is estimated by iterative three-stage least squares using annual data from 1955 to 2003. The results reveal that there has been significant oligopoly and oligopsony power in the U.S. paper industry, and the oligopoly power has been consistently lower than the oligopsony power.

Key Words: market power, NEIO, three-stage least squares, time-varying parameters

JEL Classifications: L13, Q23

The forest products industry has been a major component of the manufacturing sector in the United States (U.S. Census Bureau 2007a). It has provided numerous job opportunities and generated income in billions of dollars. The U.S. forest products industry is usually divided into three subindustries: the lumber industry (NAICS 321 or SIC 24),[1] furniture industry (NAICS 337 or SIC 25), and paper industry (NAICS 322 or SIC 26). Among the three subindustries, the paper industry is the largest in terms of value of shipments and employment. According to the latest Annual Survey of Manufacturing (U.S. Census Bureau 2007a), in 2005 the value of shipments for the paper industry reached $163 billion, and the employment totaled 429,000, or 45% and 29% of the forest products industry, respectively.

The paper industry has several distinct characteristics. Pulpwood, the raw material for paper mills, is bulky to transport. On average, harvesting and transportation costs account for two-thirds of the delivered price for pine pulpwood (Guo, Sun, and Grebner). High transportation costs of timber materials can mitigate competition and increase the potential exercise of local market power (Murray). In addition, the paper industry is a capital-intensive manufacturing sector in the U.S. economy. While capital recovery and fixed costs remain a large component of manufacturing costs (Ince), high capital costs due to the stringent environmental regulations on the paper industry have created barriers to entry and motivated mergers and acquisitions within the industry (Asinas; Gomez).

The U.S. paper industry has become increasingly concentrated over time, as indicated by the share of value of shipments accounted for by the largest four companies

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[1] The North American Industry Classification System (NAICS) was adopted in 1997 to replace the Standard Industry Classification (SIC).

(i.e., CR4). The CR4 for the paper industry was 18% in 1954 and reached 49% in 2002 (U.S. Census Bureau 2007a). This situation has been further aggravated by increasing mergers observed in recent years (Mei and Sun). Overall, the evolution of the paper industry has made it structurally concentrated with a few big processing firms, a large number of forest landowners as timber suppliers, and numerous paper products retailers. Such an industry structure has aroused wide concerns about potential market power in both the paper products output and pulpwood input markets (Bernstein).

The objective of this study is to measure the degree of market power in the paper products output and pulpwood input markets simultaneously for the U.S. paper industry during the span of 1955–2003. An econometric equation system is composed of a production function and three cost share equations for pulpwood, capital, and labor inputs. The system is estimated separately with and without the specification of time-varying conjectural elasticities by iterative three-stage least squares (I3SLS). This study extends the existing literature of market power related to the U.S. paper industry by examining the time-varying oligopoly and oligopsony power jointly over the past several decades. Results from this study will be helpful in understanding the evolution of market behavior in the U.S. paper industry.

The next section provides a literature review of market power research with emphasis on the U.S. forest products industry. The third section demonstrates the primal approach within the theoretical framework of industrial organization. The econometric specification is outlined in the fourth section, which is followed by the data section. Empirical results are discussed in the sixth section, and the final section concludes the paper.

Literature Review

As summarized by several excellent reviews, market power possessed by industrial firms has been an issue of great interest (e.g., Bresnahan; Digal and Ahmadi-Esfahani). Overall, there have been two major parametric methods in measuring market power: the structure-conduct-performance paradigm (SCPP) approach and the new empirical industrial organization (NEIO) approach. Prior to the 1980s, the SCPP approach was the dominant method. Based on the assumption that the level of competition could be implied by an industry's structural features, the SCPP approach tries to establish a direct linkage from industry structure to conduct. However, the SCPP approach has been criticized during and after the 1980s because the relationship between industry structure and conduct is not unambiguously predicted by the theory of imperfect competition, and high concentration in an industry does not necessarily imply noncompetitive behavior (Ronnila and Toppinen).

To examine 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 conjectural elasticities, also known as market conduct parameters. Conjectural elasticities measure the overall market reaction to an individual firm's change in output supply and input demand. Our review of the NEIO studies reveals two features particularly related to the objective of this study. One feature is that most efforts in the NEIO literature have been spent to investigate oligopoly or oligopsony power at one stage of the market, typically the processing sector, while maintaining implicitly an assumption of perfect competition at other stages of the market. Research that considers both markets simultaneously has been limited (e.g., Alston, Sexton, and Zhang; Azzam and Pagoulatos; Schroeter; Sexton; Wann and Sexton). Models that focuses only on oligopoly or on oligopsony power run the risk of understating the extent of market power distortion or erroneously attributing distortions to the wrong form of market power because any structure bases for concern about oligopoly power usually imply parallel concerns about oligopsony power and vice versa (Sexton).

The other feature is that many NEIO models measure market power by point estimates of conjectural elasticities using time series data. One restrictive aspect of these studies is that they constrain conjectural elasticities to be constant throughout the sample period. Therefore, these studies are incapable of addressing one important question in market power research: Has market power of an industry changed with evolving industry structure over time? Some studies (e.g., Schroeter and Azzam) have allowed conjectural elasticities to vary through time. Conjectural elasticity is usually expressed as a function of some exogenous explanatory variables. By substituting the expression into the system of equations for econometric estimation in a stochastic framework, the time-varying market power index can be calculated using the parameter estimates and the determining factors.

For the paper industry, market power research and application of the NEIO approach have been limited. Most of these studies are conducted in Canada, Finland, Norway, and Sweden. Bernstein finds competitive behavior in both the output and input markets in the Canadian sawmill and paper industries after accounting for capital adjustment costs. Ronnila and Toppinen apply duality to derive the factor demand system, and the static estimation shows that the pulpwood market in Finland has been competitive from 1965 to 1994. Based on data for individual Norwegian sawmills from 1974 to 1991, Stordal and Baardsen incorporate cross-sectional and temporal effects in examining price-taking behavior, and market power is found for some time periods. Bergman and Brannlund test market power for the Swedish pulpwood market. The estimates of strongly time-varying conjectural elasticities indicate an unstable cartel situation. Bergman and Nilsson find only weak evidence of market power for the Swedish pulp and paper industry by a conjectural elasticity model using industry data from 1970 to 1993.

Several studies have been conducted for the paper industry in the United States. Murray examines oligopsony power in both the U.S. pulpwood and sawlog markets. The wood input is modeled as a quasi-fixed factor, so its shadow price can be estimated from a flexible-form profit function. To explore time-varying market power index, a polynomial function of fuel cost and average mill capacity is employed. The results reveal that the U.S. pulpwood market is more oligopsonistic than the sawlog market. Based on the single-equation analysis, Yerger examines market power in the U.S. pulp export market. While imperfect competition is found in the chemical pulp export market, there is no clear evidence for either perfect competition or presence of market power in the U.S. sulfate pulp export market. Asinas tests market power of the U.S. paper and lumber industries, and his findings are consistent with Murray's except the magnitudes of market power exertion. Most recently, Hervani analyzes the impact of market power on the recycled newspaper market. Using an index analogous to the Lerner index, he finds some oligopsonistic behavior among the recycled-content newsprint manufacturers, and the oligopsony market power enables these mills to exert a larger price-cost margin in the recycled newspaper input market.

Given the importance of the paper industry to the U.S. economy and the limited research in testing oligopoly and oligopsony power jointly in the U.S. paper industry, there has been a great need to examine its industrial organization, especially after the frequent restructuring activities in recent decades.

Theoretical Framework

There are generally two approaches in the theoretical framework of conjectural elasticity (Wann and Sexton). The primal production function-based approach begins with the specification of a profit function. In optimum, when profit is maximized, the input demands can be obtained by Hotelling's lemma. In contrast, the dual cost function–based approach starts with the identification of a cost function. In optimum, when cost is minimized, the input demands can be derived by Shephard's lemma. In either way, the system of equations for output production and input demands in equilibrium can be jointly estimated and the conjectural elasticity can be identified. However, the dual approach is limited in deriving an expression for the conjectural elasticity in the factor market unless the production technology is restricted to consist of fixed proportions between the output and the input purchased with oligopsony power. Consequently, the conjectural elasticities in the output and input markets turn out to be identical since the quantities of output and input can be represented by the same variable with appropriately chosen dimensions (Schroeter). In this study, we choose to use the primal approach to test price-taking behavior in the U.S. paper industry without restricting the conjectural elasticities in the output and input market to be identical.

Consider the U.S. paper industry with N firms. A representative firm (j) produces a homogenous output (q_j) using inputs of wood (x_1), labor (x_2), capital (x_3), and nonwood materials (x_4) with prices w_1, w_2, w_3, and w_4, respectively. Assume the firm exercises market power in selling its paper products output and in purchasing the pulpwood input, but it is a price taker in the markets for other inputs. Furthermore, assume each firm is profit maximizing so the optimum for firm j ($j = 1, 2, \ldots, N$) is to choose input x_{kj} ($k = 1, 2, 3, 4$) that maximizes its profit.

Based on these assumptions, the NEIO approach begins with defining the following three functions (Azzam and Pagoulatos): the jth firm's production function, the inverse output demand function for the industry, and the inverse supply function of the pulpwood input:

$$(1) \quad q_j = f\left(x_{1j}, x_{2j}, x_{3j}, x_{4j}\right),$$

$$(2) \quad P = g(Q),$$

$$(3) \quad w_1 = h(X_1),$$

where P is the market price for paper products; $Q = \sum_{j=1}^{N} q_j$ is the total industry output; and $X_1 = \sum_{j=1}^{N} x_{1j}$ is the total industry pulpwood input.

The profit for the jth firm can be calculated as

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

subject to Equations (1)–(3). The first-order conditions corresponding to this profit maximization require that the marginal value product of an input equals the perceived marginal cost of the input, which yields the following equations:

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

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

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 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; $\phi_j = \partial X_1 \times x_{1j}/(\partial x_{1j} \times X_1)$ is the jth firm's conjectural elasticity in the input market; and $f_{x_{kj}} = \partial q_j / \partial x_{kj}$ is the marginal product of the kth input used by firm j.

Conjectural elasticities (θ_j and φ_j) provide benchmarks in examining price-taking behavior or the degree of competitiveness (Appelbaum). The parameter $\theta_j \in [0, 1]$ measures departures from competition in selling the output. The value $\theta_j = 0$ denotes perfect competition; $\theta_j = 1$ denotes pure monopoly; and other values denote various degrees of oligopoly power with higher values of θ_j denoting greater departures from competition. The parameter 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 practice, absence of price and quantity data for the output and inputs at the firm level generally results in considering the problem at the industry level. In doing so, an additional assumption needs to be maintained to make the preceding analysis applicable to the behavior of an industry as a whole. The assumption is that, in equilibrium, the conjectural elasticities are invariant across firms (Appelbaum), i.e., $\theta_j = \theta$, and $\phi_j = \phi$, $j = 1, 2, \ldots, N$, so that all the firms face identical marginal prices. As a result, the aggregate analogue of the optimality conditions can be written as

$$\text{(7)} \quad \frac{w_1}{P} = \left(1 + \frac{\theta}{\eta}\right) f_{x_1} - \frac{w_1}{P}\frac{\varphi}{\varepsilon},$$

$$\text{(8)} \quad \frac{w_k}{P} = \left(1 + \frac{\theta}{\eta}\right) f_{x_k}, \quad k = 2,3,4.$$

The foregoing model is similar to that by Zhang and Sexton in that both oligopoly and oligopsony power are considered within a single framework. However, it is more general since the assumption of fixed proportions is relaxed (Kinnucan). The null hypothesis in this study is that the conjectural elasticities in the U.S. paper industry equal zero. Rejecting it should suggest that the U.S. paper industry exerts market power in either the products market or factor market, or both.

Econometric Model

In order to estimate the model described above, specifications of the functional forms are needed. Selecting a functional form for the production function will lead to a system of empirical equations. It is desirable that the functional form does not impose severe *a priori* constraints on the production characteristics of the industry. One functional form that has been generally adopted is the transcendental logarithmic (translog) production function (Christensen, Jorgenson, and Lau):

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

where Xs are total industry inputs of pulpwood, labor, capital, and nonwood materials; Q is total industry output of paper products; and βs are coefficients. The translog production function is symmetric in coefficients, i.e., $\beta_{ik} = \beta_{ki}$. From the above equation, the marginal product for the kth input is

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

Substituting Equation (10) into Equations (7) and (8) leads to the following cost share equations:

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

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

where $S_k = w_k X_k/(PQ)$ is the cost share equation for the kth input (k = 1, 2, 3, 4).

Static Estimation by I3SLS

Equations (9), (11), and (12) constitute a system of five equations in total. For empirical estimation, the production function and the cost share equations are assumed to be stochastic because of technical and optimization errors. The errors are assumed to be additive and jointly normally distributed with zero mean and constant variance-covariance matrix. However, in this study, the cost share equations for S_1 and S_4 possesses a special property in that for each observation the nonwood materials cost is derived from pulpwood input cost and therefore S_1 and S_4 add up to the cost share of total material input. Hence only three of the four cost share equations are linearly independent. This dependency implies that the information in the cost share equations is redundant and the disturbance variance-covariance matrix is singular. The most common procedure for handling this singularity problem is to drop an arbitrary equation and then estimate the remaining ones (Berndt; Bhuyan and Lopez). Berndt has proved that all parameter estimates and estimated standard errors will be invariant to the choice of the cost share equation to be excluded as long as maximum likelihood or I3SLS estimation procedure is employed. Since the pulpwood input market is of concern, we choose to drop the cost share equation for the nonwood materials. The resulting system consists of a production function and three cost share equations for pulpwood, capital, and labor inputs.

When estimating the system, highly aggregated data are used so output and inputs are assumed to be endogenous. To deal with endogeneity problems in the simultaneous equations, we employ an instrumental variable estimator, I3SLS. The eight instrumental variables included in the estimation are the price for each of the four inputs, the national four-firm concentration ratio for the U.S. paper industry (m_1), average mill capacity (m_2), per capita disposable income (m_3), and a time trend (m_4). Furthermore, as exogenous point estimates of the price elasticities, -0.4 and 0.3 are used for η and ε, respectively (Newman; Newman and Wear; Sun).

Estimation by I3SLS with Time-Varying Parameters

The above econometric specification can only estimate the static market conduct parameters, θ and φ. It cannot measure and demonstrate their possible changes over time. Following previous research (Murray; Schroeter and Azzam), the equilibrium market conduct parameters are taken to be a function of the exogenous variables

$$(13) \quad \theta = \theta_0 + \theta_1 m_1,$$

$$(14) \quad \varphi = \varphi_0 + \varphi_1 m_2 + \varphi_2 m_2^2,$$

where m_1 and m_2 are defined above as the national four-firm concentration ratio and average mill capacity. This allows θ and φ to vary over time, reflecting changes in the economic environment.

Expression (13) and (14) can be substituted into Equations (11) and (12) and included in the system of equations for econometric estimation. Fitted values of time-varying market conduct parameters, thetâ and phî, can be computed using the observed values for the determining factors. Their respective variance is computed by the Delta method (Greene) using the covariance matrix of its components' parameter estimates. The statistical significance of the degree of market power is determined by t-statistics. For both static and time-varying estimation, the sample consists of annual data from 1955 to 2003. All estimations are carried out using econometric software EViews 5.

Data Sources and Variable Definitions

In this study, the U.S. paper industry is defined to include paper mills and paperboard mills (NAICS 32212/32213 or SIC 2621/2631). The pulp mills sector (NAICS 32211 or SIC 2611) is excluded because the output from the pulp mills is an intermediate input in paper manufacturing. Most wood pulp is produced and transferred within the paper and paperboard sector (Murray), so including this sector would overestimate the total industry output. Annual data series from 1955 to 2003 are constructed for each variable. The definitions, data sources, and descriptive statistics of these variables are presented in Table 1.

Specifically, the quantity of paper products output (Q) is defined as the domestic production of paper and paperboard in the U.S. paper industry. Data for 1965–2002 come from Howard and the rest from the National Agricultural Statistics Service. The value of paper products output (PQ) is needed in computing the cost share for each input. It is approximated by the industry value of shipments plus change in inventory (U.S. Census Bureau 2007a).

For specific factors, the quantity of wood (X_1) is the amount of pulpwood, chips and residues, and recycled materials used by the paper industry. Data for 1965–2002 are from Howard and the rest from Adams, Haynes, and Daigneault, and the National Agricultural Statistics Service. The price of wood (w_1) is calculated as volume-weighted average delivered price of softwood pulpwood, hardwood pulpwood, and chips and residues. Delivered prices of specific wood types for the southern states from Norris is used to represent the national timber price.

The quantity of labor (X_2) is the total annual hours of production and nonproduction workers (U.S. Census Bureau 2007a). The number of nonproduction workers is defined as the difference between the numbers of total employees and production workers, and furthermore each nonproduction worker is as-

Table 1. Variable Definition, Data Sources, and Descriptive Statistics

Symbol	Variables	Definition and data sources	Mean	SD
Q	Quantity of paper products output	Domestic production of paper and paperboard (10^6 short tons)[a]	61.86	20.79
PQ	Value of paper products output	Industry value of shipments plus changes in inventory (10^9 \$)[b]	30.51	23.78
X_1	Quantity of wood	Pulpwood, chips and residues, and recycled materials consumed by the industry (10^6 std. cords)[c]	71.95	19.56
w_1	Price of wood	Volume-weighted average delivered price (\$/std. cords)[d]	36.16	17.63
X_2	Quantity of labor	Total annual hours of production and nonproduction workers (10^6 hours)[b]	404.90	38.50
w_2	Price of labor	Total compensation of employees,[b] divided by X_2 (\$/hour)	14.46	10.92
X_3	Quantity of capital	Sum of the value of net depreciable and depletable assets, land, and inventories (10^9 \$)[e]	24.50	22.67
w_3	Price of capital	Sum of interest, depreciation, depletion and tax expenses,[e] divided by X_3	0.16	0.03
w_4	Price of nonwood materials	Price index of intermediate inputs in manufacturing[f]	76.30	39.66
X_4	Quantity of nonwood materials	Total cost of materials[b] less the cost of wood input, divided by w_4	136.97	59.33
m_1	Concentration ratio	Share of value of shipments by the largest four companies[b]	28.79	9.23
m_2	Average mill capacity	Total quantity of pulpwood input divided by the number of total establishments (10^3 std. cords)[b]	114.24	47.09
m_3	Per capita disposable income	Per capita disposable income in the U.S. (10^3 \$)[g]	10.67	8.44
m_4	Time trend	Calendar year minus 1954	25.00	14.29

[a] Howard and the National Agricultural Statistics Service.
[b] U.S. Census Bureau (2007a).
[c] Adams, Haynes, and Daigneault; Howard; and the National Agricultural Statistics Service.
[d] Adams, Jackson, and Haynes; Norris.
[e] Internal Revenue Service.
[f] U.S. Census Bureau (2007b).
[g] Bureau of Economic Analysis

sumed to work 2,000 hours per year (Murray). Total cost of labor equals total compensation for employees, and it comprises payroll, mandated benefits such as social security, and other employer-supplied benefits (U.S. Census Bureau 2007a). The price of labor (w_2) is equal to the total cost of labor divided by the quantity of labor.

The quantity of capital (X_3) is defined as the sum of the value of net depreciable and depletable assets, land, and inventories used by the U.S. paper industry (Internal Revenue Service), following Azzam and Pagoulatos. The cost of capital is calculated as the sum of interest, depreciation, depletion, and tax expenses. A two-year average is used because the data from the Internal Revenue Service have been based on the fiscal year from July to June while the calendar year is used in this study. The price of capital (w_3) equals the cost of capital divided by the quantity of capital.

The price of nonwood materials (w_4) is approximated by the price index of intermediate inputs in manufacturing for the paper industry (U.S. Census Bureau 2007b). The value of nonwood materials is computed as

Table 2. Estimates of the Parameters and Conjectural Elasticities for the U.S. Paper Industry by I3SLS

Parameter	Estimate	t-Statistic	p-Value
β_0	21.024	2.493	0.014
β_1	−4.836	−3.011	0.003
β_2	−0.093	−0.095	0.924
β_3	−0.318	−0.579	0.563
β_4	5.192	2.556	0.011
β_{11}	0.717	3.686	0.000
β_{12}	0.104	1.444	0.150
β_{13}	−0.020	−0.412	0.681
β_{14}	−0.595	−2.874	0.005
β_{22}	0.031	0.320	0.749
β_{23}	0.019	0.535	0.593
β_{24}	−0.200	−1.816	0.071
β_{33}	0.073	2.307	0.022
β_{34}	0.004	0.053	0.958
β_{44}	0.480	1.273	0.205
Conjectural elasticity			
Output market θ	0.235	7.664	0.000
Input market φ	0.516	2.409	0.017
Model performance			
Equation	Adj. R^2	Jarque-Bera	p-Value
$\ln Q$	0.978	2.111	0.348
S_1	0.800	0.097	0.953
S_2	0.600	2.974	0.226
S_3	0.823	2.111	0.348
Wald test: ($\theta = \varphi$)			
Test statistic	Value	df	p-Value
Chi-square	1.378	1	0.241

the total cost of materials less the cost of pulpwood input (i.e., w_1X_1). The total cost of materials includes the cost of raw materials put into production or used for repair and maintenance, cost of products bought and sold in the same condition, cost of fuels consumed for heat and power, cost of purchased electricity, and cost of contract work (U.S. Census Bureau 2007a). The quantity of nonwood materials (X_4) is equal to the value of nonwood materials divided by its price.

Several instrumental variables are constructed for the estimation by I3SLS. The industry concentration ratio (m_1) is approximated by CR4 in the paper industry (U.S. Census Bureau 2007a). Average mill capacity (m_2) is defined as the total quantity of pulpwood input divided by the total number of establishment in the paper industry (U.S. Census Bureau 2007a). Per capita disposable income after taxes (m_3) comes from the database maintained by the Bureau of Economic Analysis. The time trend (m_4) is defined as the difference between the calendar year and 1954.

Empirical Results

The estimation results by I3SLS are reported in Table 2. The model fits well according to several descriptive statistics. The Jarque-Bera statistics fail to reject the hypothesis of multivariate normal distribution of error terms for all four equations. The highest adjusted R^2 is 0.978 for the production equation, and the lowest is 0.600 for the cost share equation of labor input. By t-statistics, 8 of the 17 parameter estimates are significant at

Table 3. Estimates of the Parameters for the U.S. Paper Industry by I3SLS with Time-Varying Parameters

Parameter	Estimate	t-Statistic	p-Value
β_0	21.367	2.151	0.033
β_1	−4.467	−2.415	0.017
β_2	0.004	0.004	0.997
β_3	−0.975	−1.547	0.124
β_4	5.330	2.408	0.017
β_{11}	0.598	2.822	0.005
β_{12}	0.130	1.695	0.092
β_{13}	0.050	0.843	0.401
β_{14}	−0.559	−2.614	0.010
β_{22}	−0.024	−0.227	0.820
β_{23}	0.037	0.987	0.325
β_{24}	−0.249	−2.080	0.039
β_{33}	0.128	2.978	0.003
β_{34}	−0.155	−1.456	0.147
β_{44}	0.745	1.911	0.058
θ_0	0.218	6.206	0.000
θ_1	0.000	1.595	0.113
φ_0	0.577	1.938	0.054
φ_1	−0.002	−0.470	0.639
φ_2	0.000	1.064	0.289
Model performance			
Equation	Adj. R^2	Jarque-Bera	p-Value
$\ln Q$	0.978	2.605	0.272
S_1	0.830	0.953	0.621
S_2	0.554	3.693	0.158
S_3	0.860	0.922	0.631

the 5% significance level. For the key parameters of conjectural elasticities, the estimates for output and input markets are 0.235 and 0.516, respectively. Both of them are significant at the 5% significance level or better. This implies that there exists significant market power in both the paper products output and the pulpwood input markets. However, the hypothesis of identical degree of market power in both output and input markets could not be rejected based on a Wald test at the 5% significance level.

In contrast to the static estimation, the adapted model with time-varying parameters allows conjectural elasticities to change over time. The parameter estimates and the statistics for the model are reported in Table 3. The magnitude of parameter estimates and overall fit are comparable to those from static I3SLS estimation. Time-varying conjectural elasticities from 1955 to 2003 are generated by fitted values of Equations (13) and (14). The standard deviations of the conjectural elasticities computed by Delta Method allow tests of its statistical significance. These time-varying conjectural elasticities are presented in Table 4.

For the paper products output market, the conjectural elasticity estimates have been significant at the 1% level throughout the whole sample period. The estimate of oligopoly power ($\hat{\theta}$) is relatively steady with a small increase over time. The positive sign of θ_1 confirms the intuition that the more concentrated the industry, the more potential oligopoly power. In addition, the oligopoly power in the output market has been consistently below the oligopsony power in the wood input market over the sample period. The measured departures from competition are small with

Table 4. Market Power Indices for the U.S. Paper Industry from 1955 to 2003

	Oligopoly Power (paper products output)		Oligopsony Power (pulpwood input)	
Year	θ	*t*-statistic	φ	*t*-statistic
1955	0.2260	6.8443	0.5249	2.2980
1956	0.2264	6.8789	0.5243	2.3024
1957	0.2268	6.9134	0.5246	2.2999
1958	0.2273	6.9477	0.5246	2.3004
1959	0.2277	6.9819	0.5233	2.3088
1960	0.2281	7.0159	0.5231	2.3097
1961	0.2285	7.0497	0.5229	2.3113
1962	0.2289	7.0832	0.5228	2.3122
1963	0.2293	7.1166	0.5230	2.3119
1964	0.2292	7.1083	0.5235	2.3106
1965	0.2289	7.0832	0.5230	2.3119
1966	0.2291	7.0999	0.5237	2.3098
1967	0.2293	7.1166	0.5235	2.3106
1968	0.2295	7.1276	0.5250	2.3063
1969	0.2296	7.1388	0.5269	2.3014
1970	0.2298	7.1497	0.5263	2.3029
1971	0.2297	7.1415	0.5272	2.3007
1972	0.2285	7.0497	0.5314	2.2928
1973	0.2284	7.0429	0.5352	2.2877
1974	0.2283	7.0362	0.5353	2.2876
1975	0.2283	7.0294	0.5273	2.3004
1976	0.2282	7.0226	0.5360	2.2869
1977	0.2281	7.0159	0.5395	2.2839
1978	0.2280	7.0091	0.5454	2.2814
1979	0.2279	7.0023	0.5539	2.2818
1980	0.2278	6.9955	0.5574	2.2830
1981	0.2278	6.9887	0.5645	2.2872
1982	0.2277	6.9819	0.5608	2.2848
1983	0.2286	7.0530	0.5814	2.3038
1984	0.2294	7.1233	0.5981	2.3265
1985	0.2303	7.1925	0.5958	2.3232
1986	0.2312	7.2606	0.6171	2.3574
1987	0.2321	7.3275	0.6393	2.3976
1988	0.2319	7.3117	0.6518	2.4214
1989	0.2317	7.2958	0.6535	2.4246
1990	0.2314	7.2799	0.6649	2.4466
1991	0.2312	7.2638	0.6699	2.4563
1992	0.2310	7.2477	0.6917	2.4988
1993	0.2313	7.2709	0.7072	2.5287
1994	0.2316	7.2939	0.7396	2.5887
1995	0.2319	7.3168	0.7458	2.5997
1996	0.2322	7.3395	0.7555	2.6165
1997	0.2325	7.3620	0.7960	2.6813
1998	0.2338	7.4567	0.7068	2.5279
1999	0.2477	8.2024	0.7113	2.5364
2000	0.2364	7.6356	0.6945	2.5043
2001	0.2377	7.7193	0.6594	2.4359
2002	0.2390	7.7988	0.6413	2.4014
2003	0.2390	7.7988	0.5987	2.3275

values around 0.2, the equivalent of market power from a five firm symmetric Cournot equilibrium (Kinnucan; Sexton). Over 1955–2003, the maximum value of $\hat{\theta}$ is 0.2477 in 1999, the minimum is 0.2260 in 1955, and the average is 0.2310.

For the pulpwood input market, the conjectural elasticity estimates have been significant at the 5% level for the sample period. The estimate of oligopsony power ($\hat{\varphi}$) decreased slightly until 1962 when it begins to increase. In 1997, it peaks at 0.796 and then levels off to the average. As an indicator of price competition at the spatial market boundaries (Murray), the negative sign of average mill capacity (φ_1) suggests that the more intensive the border competition is, the lower oligopsonistic tendency is for mills to restrict pulpwood inputs. Over 1955–2003, the maximum value of $\hat{\varphi}$ is 0.7960 in 1997, the minimum is 0.5228 in 1962, and the average is 0.5922.

In summary, the null hypotheses of price-taking conduct in both the paper products output and pulpwood input markets are rejected. The U.S. paper industry has tended to exert both oligopoly and oligopsony power over the past several decades. While the oligopoly power remains stable with a trend of a slight increase, the oligopsony power has fluctuated over time. For the whole sample period, the oligopoly power has been consistently lower than the oligopsony power.

Conclusions

Market power studies for the paper industry generally examine one side of the market. Studies addressing market power on both output and input markets simultaneously have been limited. Furthermore, the majority of previous studies have employed static estimation and they are limited in revealing the time-varying characteristics of market power indices. In this study, the NEIO approach and econometric model with time-varying parameters are combined to examine the market behavior of the U.S. paper industry. Annual data from 1955 to 2003 are used in the estimation. This study extends the market power research in the U.S. paper industry by examining the dynamics of market power in both output and input markets simultaneously.

The empirical results reveal the presence of market power in both the paper products output and pulpwood input markets in the past several decades. The rapid growth in oligopsony power from the mid-1980s is likely explained by an increasingly geographically concentrated pulpwood market over that period, whereas the downturn of oligopsony power since the late 1990s coincides with the expanding use of recycled materials in the U.S. paper industry. Haynes shows that use of recycled materials mitigates the demand for virgin wood fiber. The impact of market power exertion in the U.S. paper industry has been twofold. In the paper products output market, the oligopoly power is expected to reduce demand for paper products output, whereas in the pulpwood input market, the oligopsony power is expected to depress pulpwood input price. This is evidenced by declining per capita consumption of paper and persistent low prices for softwood pulpwood for the past 10 years (Wear, Carter, and Prestemon). Collectively, the oligopoly and oligopsony power may allow the paper industry to advantageously adjust production and operate with greater profit margins. Market power presence in the U.S. paper industry also implies an inefficient allocation of resources, a reduction in consumer and producer surpluses, and therefore a loss in social welfare (Asinas).

It should be noted that although the NEIO approach can detect the degree of market power, it is limited in identifying its sources (Bresnahan). In this study, the oligopoly power is assumed to change with the national four-firm concentration ratio, whereas the oligopsony power is assumed to vary with average mill capacity. However, those specifications are subjective. Other factors, like market shocks, economic cycles, environmental regulations, and international trade, have also been perceived to be related to market power in the U.S. paper industry (Asinas). Given the results of market power variation in the U.S. paper industry over time, this study brings up several interesting questions. Future research can examine what factors determine the variation in market power; how market power influences the welfare of forest landowners and paper products retailers; and what the implication is to investments in the forestry and forest products industry.

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