

**Industry Consolidation and Price:  
Evidence from the U.S. Linerboard Industry**

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**Abstract**

Starting from the 1980's, the U.S. paper and paperboard industry has recorded an increasing degree of consolidation through mergers and acquisitions. This strategy, combined with voluntary downtime, is adopted by producers as a mean to tackle excess capacity and to reduce costs in order to improve profitability. However, it is unclear whether the rising market concentration resulted in market power. In this study, we investigate the impact of industry consolidation on price in the linerboard industry. We estimate a dynamic demand/supply system model that explicitly incorporates market structure, using monthly data from January 1982 to December 1999. As shown in our results, the price is mainly influenced by consumption and material cost. We also find that operating rate has positive and statistically significant impacts on price. However, market concentration does not show any statistically significant effects on price.

**Keywords:** Industry consolidation, price, market structure, demand and supply system, paperboard industry

## 1. Introduction

Consolidation is often suggested as a solution to improve profitability when an industry on the whole is facing a lackluster performance. One of the central issues regarding industry consolidation concerns the relationship between concentration and firm performance. A rich body of empirical researches (Demsetz 1974; Peltzman 1977; Salinger 1990, etc.), spanning various industries and time periods, suggests that higher levels of concentration are usually associated with higher profit margins. However, it is generally unclear if the improved profit margins are caused by higher price, lower cost, or both, as a result of consolidation. The answer to this question will have different implications for the industry.

Starting in the 1980's, the U.S. paper and paperboard industry adopted the strategy of consolidation, combined with voluntary downtime, to tackle excess capacity, involuntary inventory buildup, and volatile price movement. This trend continued and accelerated through the 1990's. From 1970 to 1979, the average annual number of mergers in the pulp, paper, and paperboard sectors was 4, and from 1980 to 1989, this number increased to 7. During the 1990s, there were 9 mergers per year. The most active merger activity was observed in the paperboard industry, with a record 35 mergers in 1998. Over the period of 1983-2000, the U.S. linerboard industry alone witnessed 33 mergers and acquisitions. Consequently, market concentration for the U.S. linerboard industry increased steadily over the last two decades. Based on the Pulp & Paper North America Factbook, the five largest linerboard companies in 1980 had about 34.1 percent of the total capacity and the top ten companies had about 57.5 percent. In 2001, however, the top five U.S. linerboard producers managed 66.5 percent of U.S. linerboard capacity.

In light of increasing mergers and acquisitions in the U.S. paper and paperboard industry, researchers are interested in whether the rising market concentration has conferred market power. Although the level of concentration measured by the share of top four producers is not particularly high (in the range of 35-40%), a certain degree of market power in linerboard industry is still possible given geographic segmentation of markets due to high transportation cost. In general, linerboard is bulky and thus costly for long-distance shipping. A few existing studies for the paper and paperboard industry

indicate the existence of oligopolistic structure. For instance, Rich (1983) describes the process of price determination in paper and paperboard industries as “target-return pricing, tempered by marginal cost pricing”, i.e., prices are set on a target return basis during periods of strong demand but approach to the marginal cost during periods of weak demand. Buongiorno and Lu (1989) find that increases in inventory-output ratios always lead to decreases in prices, which supports the hypothesis of mark-up pricing behavior in pulp and paper industries. More recently, Booth et al. (1991) find that operating rates have significant influence on price in North American newsprint, suggesting the existence of barometric price leadership.<sup>1</sup>

By contrast, industrial analysts believe that stiff competition remains in the U.S. containerboard industry, even though the industry is only comprised of a few homogeneous products and the concentration level in this industry keeps rising. They argue that many paperboard products are selling into markets so full of competition that large producers enjoy little leeway to raise prices.<sup>2</sup> Taking linerboard -- the largest segment of paperboard industry for example, analysts believe that the linerboard market is so fragmented that many producers are fighting for market shares and the price is down to the marginal cost.<sup>3</sup> Given the on-going antitrust litigation against Smurfit-Stone Container Corporation (SSCC), one of the largest linerboard manufacturers, questions of whether market power exists, to what extent the market power reaches, and what its impact is on price are of particular importance to the U.S. linerboard industry.

A few studies have been conducted to understand what factors determine the price of paper and paperboard products, yet few addressed the relationship between price and industry consolidation in a dynamic demand/supply system. Dagenais (1976), for instance, presents a model of price determination for newsprint in eastern North America. Chas-Amil and Buongiorno (1999) examine the determinants of

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<sup>1</sup> Under barometric price leadership, the price leader acts as a barometer of market conditions, setting price approximating the marginal cost.

<sup>2</sup> Dylan Rivera (2003), “Nuts ‘n’ Bolts of Efficiency”. The article states: “The biggest producer is still going to be a price taker. That is why it’s so important to control things that are in your control, which tend to be manufacturing costs.”

<sup>3</sup> Alby Gallun (1998), “Cardboard Companies seek price stability”, *Business Journal*.

the prices of paper and paperboard in the European Union. Because price is determined in a simultaneous demand and supply system, those existing studies that ignore demand side will lead to biased results. Specifically, the ability of keeping price high is not only determined by industry concentration but also affected by demand side factors, such as price elasticity, available substitutions, and macroeconomic performance. For example, in face of weak demand and excess capacity, producers have more incentives to deviate from price coordination. Scherer (1980) points out that the degree of market power is generally overstated when substitutes are excluded or when import competition is significant and understated when sellers enjoy strong product differentiation advantages.

In this study, we attempt to fill the gap in the literature by investigating the impact of industry consolidation on price in the linerboard industry. We estimated a dynamic demand/supply system to examine the relationship between demand, costs, and price. One unique feature of our approach is that we develop a simultaneous equations model and explicitly incorporate mark-up factors into the model. Therefore, we can investigate the role of industry consolidation.

The paper is organized as follows. In section II, we provide an overall description of the U.S. linerboard industry. Section III develops empirical models for the demand and supply system. Section IV briefly describes the data. Section V discusses the results; and section VI concludes.

## **2. The U.S. Linerboard Industry**

Linerboard and corrugating medium, referred together as containerboard, are the main materials used to produce corrugated shipping containers. The U.S. linerboard market is of particular interest because of its economic significance as well as recent merger activities and antitrust cases. First, it is one of the largest yet least differentiated segments of the paperboard industry. In 1999, for example, the production of the linerboard industry accounts for about 49% of total U.S. paperboard production. The U.S. by itself produced 24.7 million short tons of linerboard, accounting for 66.1% of the world's total production and an estimated 57.9% of the global supply. Because linerboard is bulky and the transportation cost is high for long distance shipping, U.S. imports and exports of linerboard are relatively

small. Although the U.S. is the largest exporter of Kraft linerboard in the world, only about 10 percent of annual linerboard production is sent abroad. Most of the linerboard produced in the U.S. goes into domestic corrugated container production processes.<sup>4</sup> As for imports, even at its highest level in 1999, the import was still below 3% of the domestic production. International markets play a relatively small role in the U.S. linerboard demand/supply system.

Linerboard has relatively fewer grades compared with other paper and paperboard products. The majority of linerboard traded is unbleached Kraft linerboard, which represents 82% of total linerboard shipment in 1998. Recycled (test) linerboard accounts for less than 18% of domestic production. Unbleached linerboard is made in a number of basis weights, of which the most common is 42 lb (lb/1000 sq. ft.), representing about 50% of total U.S. production. Other important grades are produced in weights of 26, 33, 38, 69 and 90 lb.<sup>5</sup>

In 1980, the five largest firms had about 34.1 percent of the total capacity and the top ten firms had about 57.5 percent. Due to recent merger activities, today's U.S. linerboard industry has become more concentrated. The five largest producers of linerboard in 1998 controlled nearly 50 percent of U.S. linerboard capacity and the ten largest companies account for nearly 74 percent. In 2001, the top five U.S. linerboard producers -- SSCC, International Paper, Georgia-Pacific Corp., Weyerhaeuser, and Inland Paperboard and Packaging Co. -- managed 66.5 percent of U.S. linerboard capacity.<sup>6</sup>

Most containerboard producers are also integrated with corrugated box firms. Integrated producers are those who make the materials needed for boxes -- linerboard and corrugating medium, as well as the boxes. In terms of the corrugated box industry, about 80% of the corrugated box capacity in the U.S. is integrated with companies that produce containerboard, while the remaining 20% consists of independent converters. In terms of the containerboard market, only 25% of containerboard produced is sold on the open market to independent converters and customers outside the U.S. The remaining 75% of

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<sup>4</sup> The statistic source is *The International Fact & Price Book 2002*.

<sup>5</sup> The statistics sources include '*AFPA Statistics for Time Series Analysis 1999*', and '*International Fact & Price Book 2002*'. The measurement unit is defined as short tons here and through this study as well.

<sup>6</sup> Concentration ratios are calculated based on the statistics from *Pulp & Paper 2001 North American Factbook*, which are larger than those from the database provided by the Forrest Products Laboratory.

tonnage is either supplied by integrated producers to their own box plants, or traded with other integrated producers to save on freight costs.<sup>7</sup>

Notwithstanding the intensifying consolidation activities, price remains volatile in the past decade. In general, domestic linerboard prices tend to be cyclical, usually rising when the economy grows but falling when demand weakens during slowdown. As shown in Figure 1, the unbleached Kraft linerboard prices from 1982 to 1999 are noted with four major declines. The price drops happened during the years of 1984-1985, 1989-1991, 1992-1993, and 1995-1997, more or less in coincidence with the general economic recessions.<sup>8</sup> Due to the persistent overcapacity, discounting usually spreads during recessions as producers fight for available orders to keep their capital-intensive mills running at high levels. Such tactics normally backfire as other producers match the discounts, resulting in a general price reduction. However, when the economy turns around producers appear to have the most success in pushing through price increases.

Producers usually take downtime in order to fend off weak demand and maintain stable inventory levels. For instance, starting in 1998, SSCC, Weyerhaeuser, and International Paper all shut down their older plants after mergers and acquisitions.<sup>9</sup> Such practices may be subject to antitrust charges, if there is a coordinated effort of two or more manufacturers to limit supply and thus drive up prices. For instance, in 1998, the Federal Trade Commission (FTC) alleged that the Stone Container Corporation, the world's leading integrated manufacturer of linerboard, was involved in the price-fixing behavior from October 1, 1993 through November 30, 1995. According to the FTC, Stone Container Corporation, following a failed attempt to increase the price it charged for linerboard in 1993, temporarily shut down production at its own mills and bought up competitors' excess inventory as part of an intentional effort to build industry support for a price increase. The FTC claims that such actions constitute an invitation to its competitors to join in a coordinated price increase.

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<sup>7</sup> The statistic source is *Pulp & Paper 2000 North American Factbook*.

<sup>8</sup> The price drop over the period of 1995-97 was possibly caused by the large price hike in 93-95 associated with the litigation.

<sup>9</sup> Louis Uchitelle (2000), "Who's Afraid Now That Big Is No Longer Bad?" *New York Times*.

It appears that the U.S. linerboard industry exhibits a certain degree of oligopolistic structure. And it is also possible that leading producers can exercise some pricing power, for example, through either barometric price leadership or collusive price leadership.<sup>10</sup> However, it is unclear whether their market power has materialized, i.e., resulted in a higher price, given the excess capacity faced by the industry. This is certainly an empirical question. Thus, it is important to incorporate market structure into the demand/supply system model.

### 3. Model Specifications

In our model, we assume that price is determined by a mark-up over marginal cost following an oligopoly structure (Booth et al. 1991; Yamawaki 1984), thus we explicitly allow the measure of market structure in the price function. More specifically,

$$P_t^* = \lambda_t \cdot MC_t(Q_t, Z_t) \cdot \varepsilon_t \quad (1)$$

where  $P_t^*$  is the equilibrium price in period  $t$ ,  $\lambda_t$  is the mark-up factor,  $MC_t$  is the marginal cost function in period  $t$ ,  $Q_t$  is the equilibrium quantity or consumption,  $Z_t$  is a set of exogenous variables on supply side, e.g. input prices, and  $\varepsilon_t$  is the error term. When producers are price takers, price equals marginal costs and  $\lambda_t$  equals one; however, when firms are not price takers, they set a target price higher than marginal costs and then  $\lambda_t$  is larger than one. In this specification, the model can accommodate different market structures.

The mark-up factor reflects the ease of coordination in the oligopoly, being generally affected by concentration and operating rate in the industry. The coordination of price is relatively easier when the market is highly concentrated. The operating rate, on the other hand, reflects industrial conditions and demand cycle, which either facilitate coordination when the current state of demand is strong or dampen

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<sup>10</sup> Under collusive price leadership, also known as price leadership in lieu of overt agreement, price leader is conceivably so effective as to assure parallel actions from other firms. According to Markham (1951), the following five market features are prerequisites for collusive price leadership. The industry is tightly oligopolistic, entry to the industry is severely restricted, product of each firm are close substitutes, firms have similar cost curve, and demand for the industry's output is relatively inelastic.

intentional price cooperation when the demand is unexpectedly weak. Therefore, the mark-up factor can be defined as the following function:

$$\lambda_t = \delta_0 e^{\alpha_1 OR_{t-1} + \alpha_2 CR_t} \quad (2)$$

where  $OR_{t-1}$  and  $CR_t$  are the operating rate and concentration ratio, respectively. Since we will use monthly data, it is likely that producers make decisions based on the market conditions in the previous month. On the other hand, current operation rate may be highly correlated with the current demand, and then will be endogenous. Thus, the operating rate in previous time period is used in the model.

Based on Cobb-Douglas production for simplicity, the marginal cost function can be derived by minimizing total cost, and is defined as:

$$MC(Q_t, Z_t) = \psi_0 (Q_t)^{\alpha_1} (W_t)^{\alpha_2} (P_t^m)^{\alpha_3} (P_t^e)^{\alpha_4} \quad (3)$$

where  $W_t$ ,  $P_t^m$ , and  $P_t^e$  are the price of labor, materials, and energy at time  $t$ .<sup>11</sup> In order to allow the actual price to gradually adjust to the desired level, we define the adjustment mechanism as following:

$$\frac{P_t}{P_{t-1}} = \left( \frac{P_t^*}{P_{t-1}} \right)^\tau \quad (4)$$

where  $P_t$  is the price level in time  $t$ ,  $P_{t-1}$  is the price in previous period,  $P_t^*$  is the desired price level, and  $\tau$  is the adjustment speed,  $0 < \tau < 1$ .

Substituting equations (3) and (2) into (1), taking the logarithm form, and then using the adjustment mechanism in (4), we obtain the following price equation:

$$\ln P_t = \alpha_0 + \alpha_1 \ln Q_t + \alpha_2 \ln W_t + \alpha_3 \ln P_t^m + \alpha_4 \ln P_t^e + \alpha_5 \ln P_{t-1} + \alpha_6 \lambda_t + \varepsilon_t \quad (5)$$

The demand for linerboard is a derived demand that arises from the demand for the container box, which is usually driven by consumption of food, beverages and chemicals, as well as durable goods.

Therefore, in general, the demand for containerboard is determined by total production in the economy, its price, and price of substitutes, based on economic theory. We define the following demand equation:

$$\ln Q_t^* = \beta_0 + \beta_1 \ln P_t + \beta_2 \ln P_t^s + \beta_3 \ln Y_t + u_t \quad (6)$$

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<sup>11</sup> Other input costs such as capital cost and transportation cost are not included partly because of data availability and partly because they represent only a small portion of the total cost.

where  $Q_t^*$  represents the desired domestic demand for linerboard,  $P_t$  is the real price of U.S. linerboard products,  $P_t^s$  is the real price indices of substitute material,  $Y_t$  is the total industrial production indices, a proxy for economic activities, and  $u_t$  is the disturbance term.<sup>12</sup> Following the same adjustment mechanism described for the price equation, we obtain a more general dynamic demand function:

$$\ln Q_t = \gamma_0 + \gamma_1 \ln P_t + \gamma_2 \ln P_t^s + \gamma_3 \ln Y_t + \gamma_4 \ln Q_{t-1} + u_t, \quad (7)$$

where  $\gamma_1, \gamma_2$ , and  $\gamma_3$  are interpreted as short-run own-price, cross-price and income elasticities of the demand, respectively; while  $\gamma_1/(1-\gamma_4)$ ,  $\gamma_2/(1-\gamma_4)$ , and  $\gamma_3/(1-\gamma_4)$  are the corresponding long-run demand elasticities. Equation (5) and (7) will be estimated as a simultaneous equation system.<sup>13</sup>

#### 4. The Data

Monthly data from January 1982 to December 1999 is used in this study. The data was collected from the American Forest & Paper Association (AFPA), the U.S. Bureau of Labor Statistics, the U.S. Federal Reserve Bank, and the Forest Products Laboratory (FPL). The linerboard price is the transacted price per short ton for 42lb unbleached linerboard and is taken from different issues of the *Official Board Markets*. The price published at the *Official Board Markets* contains three different prices for every period: the minimum price, the maximum and the average price. We use the average price and convert it into the 1982 dollar. The consumption of unbleached kraft linerboard is used as the equilibrium quantity. It is measured by subtracting monthly inventory change from the monthly output, where the inventory includes both inventory at linerboard mills and at box plants. Monthly output and inventory data are obtained from ‘*AFPA Statistics for Time Series Analysis: Monthly Production of Containerboard and Related Series: 1980-1999*’ (United States, 2000). Figure 1 shows the relationship between the real price and the consumption of linerboard. Clearly, the price varies in a very different pattern from that of the

<sup>12</sup> Another measure of economic activities commonly used in the literature is GDP. But monthly GDP data are not available.

<sup>13</sup> As discussed above, the international market is relatively unimportant for the U.S. linerboard industry, and thus is ignored in the demand and supply system.

demand. Due to many other factors in the equilibrium system, it is hard to tell visually that there is any relationship between the price and demand.

We employ the commonly used top four-firm concentration ratio to measure industry concentration. Most studies used the concentration ratio calculated based on actual production due to data limitation. Because production and price may be simultaneously determined, the output based concentration measure is likely to be endogenous. We calculate the concentration ratio based on productive capacity, which greatly reduces the concern for endogeneity given the long-term nature of capital investment in the containerboard industry. The statistic source of annual capacity is the FPL data, a panel data set with more than 20,000 annual mill counts (500 mills for 30 years), collected by the FPL of the US Department of Agriculture located in Madison Wisconsin. The data contains plant capacity information for linerboard industry. We aggregate mill capacities into company capacities on the base of corporate ownership and calculate the annual concentration ratio. The resultant annual concentration ratio is then converted into monthly values by interpolating missing values using a fitted cubic spline curve to the annual values. The operating rate is defined as the ratio of output to capacity. The data was taken from ‘*AFPA Statistics for Time Series Analysis: Monthly Production of Containerboard and Related Series: 1980-1999*’.

For linerboard producers, the major cost is pulpwood, which represents 40-50% of the total cost. Other costs include energy (10-15%), labor (10-15%), depreciation and amortization (10-15%), chemicals (10%), and transportation (5%).<sup>14</sup> The material cost is measured by the PPI for pulpwood (including hardwood and softwood). The energy cost is measured by the PPI for electricity. The labor cost is represented by the average weekly earnings of production workers at paperboard mills.

The main substitute for containerboard box is plastic containers, such as Returnable Plastic Containers. The substitution of plastics for containerboard has made inroads in certain segments of the packaging market like groceries and auto parts going to assembly lines. The price of substitute is

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<sup>14</sup> White, David E. (2002), “Redefining Core Technologies in the Pulp and Paper Manufacturing Sector”, Institute of Paper Science and Technology, *Final Report of Project No. 4251*.

measured by PPI for polypropylene resins, a main material of plastic packaging. All nominal values of costs as well as the substitution price are deflated with the PPI for all industrial commodities with 1982 as base year.

The total industrial production index, taken from the U.S. Federal Reserve Board, is used as a proxy of the economic activity. Industrial production is manufacturing production plus the supply of energy and water, and the output of mines, oil wells and quarries. It generally excludes agriculture, trade, transport, finance and all other services. Thus, the total industrial production is closely related to the production of goods that require shipment using container box, and thus drives the demand for containerboard.

Finally, the U.S. unemployment rate is used as a proxy to control for business cycle, and is from the U.S. Bureau of Labor Statistics. All variables are not seasonal adjusted. The descriptive statistics of the variables are listed in Table 1.

## **5. Empirical Results**

Price and demand functions based on equation (5) and (7) are jointly estimated by two stage least squares. The variables specified as endogenous are linerboard consumption, market price, and pulpwood price. The pulpwood price is considered endogenous, because an increase of pulpwood price will likely increase the material cost thus the linerboard price, and an increase in the linerboard price in turn boosts the demand for pulpwood and thus increases the price of pulpwood. Therefore besides the predetermined variables on both price and demand sides, the pulpwood price in the previous month is included as an instrumental variable for the current pulpwood price. Table 2 reports the estimation results for a competitive linerboard market; Table 3 presents results for models that allow for some degree of oligopoly.

Since our data are not seasonal adjusted, certain seasonality may exist. Thus, in addition to yearly dummies in model 1, we also add seasonal dummies or unemployment rates to capture seasonality/business cycle in other models. The F-statistics for overidentification in our models are

statistically insignificant and cannot reject the null. This is comforting as it suggests that there is no strong evidence against the validity of instrumental variables in both demand and supply sides. Our tests also show no evidence of serial correlations, indicating that our models are dynamic complete.<sup>15</sup>

As indicated in Model 1, linerboard price exhibits a cyclical trend but with high rigidity. The coefficient of consumption is small but statistically significant, suggesting that, in short term, a 10% increase in the market demand for linerboard leads to a 1.2% increase in price. In other words, linerboard price adjusts along with the vicissitude of consumption but tends to be rigid in the face of moderate changes of demand conditions. This coefficient is in line with those in Chas-Amil and Buongiorno (1999). The estimated coefficient of lagged price is 0.84 and highly significant, indicating a low rate of adjustment of 0.16. The low adjustment rate means that the linerboard price is sticky and remains stable with occasional price revisions. In long term, the response of price to demand becomes almost unitary.

The coefficients of the input prices have plausible signs and magnitudes, but only that before pulpwood price is statistically significant. One explanation is that raw material is the most important factor in the linerboard production and thereby has a main influence on price. Of the total cost of linerboard, pulp accounts for around 40 percent, while labor and energy only account for 10 percent and 12 percent, respectively. Buongiorno and Lu (1989) also find that a much larger portion of the rise in output price coming from unit cost was due to changes in the cost of materials than to changes in labor cost. After controlling the growth rate of material and labor cost, they find a 1% increase in material cost leads to a 0.69% increase of the price for paper mills and a 0.79% increase for paperboard mills, while a same amount increase in labor cost only raises the price by 0.25% and 0.28%. Our results, based on Model 1, show smaller price elasticity with respect to material cost, i.e., in short-term, a 1% increase in pulpwood price will cause a 0.18% increase in linerboard price. However, in long-term, the elasticity becomes 1.13, indicating a shock in pulpwood price will be eventually passed on to customers, and

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<sup>15</sup> Because the model included a lagged dependent variable, we follow Durbin (1970) to test for AR(1) error. We first regress linerboard consumption on all explanatory variables including lagged consumption by 2SLS, and obtain the residual  $\hat{\epsilon}$ . We then regress consumption on all explanatory variables and the lagged  $\hat{\epsilon}$  by 2SLS, using the same instruments, and test whether the coefficient of lagged  $\hat{\epsilon}$  is significant.

producers may even be able to rise price more to take advantage of higher material price. Thus, it seems linerboard producers can generally absorb shocks caused by price hikes in labor and energy inputs, but pass on cost shocks from pulpwood to its customers.

Demand elasticity with respect to total industrial production is from 0.61 to 0.74 and highly significant. Clearly, the linerboard demand is affected by the shipments of manufacturing and durable goods. Together with the small response of price to market demand, such results suggest that the business cycle makes a strong impact on the demand for linerboard, yet only small part of the impact can be transferred to the price. This phenomenon could attribute to the persistent overcapacity and high integration feature of the U.S. linerboard industry. During the 1980's, facing a period of rising prices and anticipating exports to Asia that have not materialized, linerboard producers overbuilt their productive capacity. Due to this overbuilt capacity, a moderate increase in demand during business expansions usually induces higher output without driving up prices. In the meantime, 80% of corrugated box capacity in the U.S. is integrated with companies that produce containerboard, and they are capable of alleviating demand shocks through stocking up or reducing inventory level at both linerboard mills and box plants.

The response of demand to price is significant but inelastic, lying in the range of -0.12 to -0.18. The small magnitude of own-price elasticity is consistent with previous studies (Buongiorno and Kang 1982; Chas-Amil and Buongiorno 2000). The less elastic demand generally suggests a higher profit-maximizing profit margin.<sup>16</sup> On the other hand, plastics appear to be a substitute for containerboard as the coefficient of plastics price is positive and significant at the 10% level. The substitution effect of plastic packaging, however, is small, with cross-price elasticity running from 0.12 to 0.14 in Table 2.

Model 2 includes seasonal dummies to capture seasonality. Except the coefficient of consumption, which changes from statistical significance to insignificance, all other coefficients remain almost the same in terms of magnitude and significance. In order to capture the effect of business cycles on the demand/supply system, we include unemployment rate in Model 3 to further control for macro-economy

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<sup>16</sup> Profit margin is defined as  $(P - MC)/P$ . When producers' goal is profit maximization then  $MC = MR = P + Q(dP/dQ) = P[1 - (dP/dQ)(Q/P)] = P(1 - 1/e)$ , where  $e$  is own-price elasticity. Rearranging the terms, we obtain  $(P - MC)/P = 1/e$ .

activities related to business cycle.<sup>17</sup> The responses of the price and demand to unemployment rate are of expected sign but insignificant. It shows that the business cycle effect is well captured by the production index and annual dummy variables (not reported in the tables). In both Model 2 and 3, consumption becomes insignificant, which is probably caused by the multicollinearity between the demand and seasonal dummies and unemployment rate.

High price rigidity, low own-price elasticity of demand, and small substitute effect seem to indicate the U.S. linerboard has an oligopoly structure. But it is unclear whether the potential market power actually existed and how the price is affected by the industry consolidation. In order to address these questions, we incorporate market structure factors in Model 4 through Model 8. More specifically, Model 4 includes the operation rate in the supply model, while Model 5 to 8 mainly investigates the effect of industry consolidation on price.

The results are quite robust and remain almost unchanged after we incorporate different market-structure factors. As indicated in models 4, 6, 7, and 8, operating rates have significantly positive effects on price setting. In general, the operating rate has a small coefficient 0.002~0.003, indicating that ten percentage point increase in operating rate in the previous month will increase the price by 2~3%, approximately a 6.2-9.3 dollar increase evaluated at the average price of \$310.97. One explanation lies in the signal effect of operating rate. Based on industry analysts, as the operating rate gets higher, buyers become concerned about future supply and thus buy even more. Such a response to operation rate helps to drive up the price.

The market concentration is measured by the ratio of the capacity of top four producers to the total capacity, a measure most commonly used in the literature. When it is included in the model to control for market structure, the concentration ratio is of expected sign but statistically insignificant. This result is robust across all specifications in Table 3. Therefore, market concentration does not appear have a statistically significant impact on price. In Model 7, unemployment is added as additional control for

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<sup>17</sup> Unemployment rate is commonly used to capture the effect of business cycle in this literature, see for example, Domowitz, Hubbard, and Petersen (1986a, 1986b).

business cycles; in Model 8, the interaction term of concentration and unemployment is included. This interaction term is to capture the possibility of a pro-cyclical behavior of market concentration on price (see for example, Domowitz, Hubbard, and Petersen 1986a, 1986b). Based on the negative sign of the interaction term, the impact of concentration on price does show a pro-cyclical pattern, i.e., the effect of concentration on price gets weaker during recession and becomes stronger during the expansion. This pattern resembles that of the impact of market concentration on price-cost margins found in Li, McCarthy, and Urmanbetova (2004). It is possible that, when the current state of demand is unexpectedly weak and leaves the producer with excess capacity, the producer is more likely to lower price in order to increase sales.

One explanation on the insignificant effect of market concentration on price is that the current level of market concentration is still too low for producers to have substantial price power. Based on Salinger (1990), in 1969 the “so-called Neal report” recommended an active policy of “deconcentration” based on evidence of 15 percent of market share held by one firm and a 70 percent by four top firms. In our sample, the level of concentration in the linerboard industry is still around 40%. Moreover, facing excess capacity, linerboard producers are more likely to restrict price in order to keep their capital-intensive mills running at high levels of capacity. In such a situation, any price coordination would be difficult.

On the other hand, rising concentration may help to increase profit margins through cost reduction instead of price increase. Li, McCarthy, and Urmanbetova (2004) investigate the effect of concentration on price-cost margin in pulp and paper industry, and find a positive relation between concentration and price-cost margin. They found that one percent increase in market concentration increased price-cost margins by 0.5 to 0.6 percentage points. If their results based on the entire pulp and paper industry hold at the more disaggregated linerboard industry level, then it is likely that industry consolidation helps to reduce costs.

## 6. Conclusion

Starting from the 1980's, the U.S. paper and paperboard industry has experienced a series of mergers and acquisitions. Consequently, market concentration for the paperboard industry, measured by the percent of total capacity due to the top four producers, steadily increased over the period of 1980 to 2000. Taking the linerboard industry for example, the market concentration raised from 29 percent in 1980 to 40 percent in 2000. In this paper, we investigate the effect of industry consolidation on price based on a dynamic simultaneous equation system model, using monthly data from January 1982 to December 1999. One unique feature of our simultaneous equations model is that we explicitly incorporate a mark-up factor into the model and the mark-up factor is assumed to be a function of operating rate and concentration ratio.

The empirical results are quite robust across different model specifications. Price is mainly influenced by linerboard consumption and material cost, and shows strong rigidity. More specifically, when the demand increases by one percent, the price will increase by approximately 0.1-0.2%. Moreover, only the price of pulpwood, one major raw material, has a positive and significant effect on linerboard price. If the current pulpwood price increases by 1%, the current linerboard price will increase by 0.18-0.43%. In long-term, however, the increase in pulpwood price seems to be fully passed on to containerboard customers. In contrast, the prices of other inputs such as labor and energy do not seem to affect the price.

The elasticity of linerboard demand with respect to total industrial production is in the range of 0.61 to 0.74 and highly significant, suggesting the demand for linerboard is sensitive to macro-economic activities. This is because that the demand for linerboard is mainly determined by the shipments of manufacturing and durable goods. The price elasticity of linerboard demand lies in the range of -0.12 to -0.18. Plastics appear to be penetrating into the containerboard market, but the impact seems to be small. When the price of plastics decreases by one percent, the demand for linerboard will decrease by 0.12-0.14%.

The results show that operating rate has a positive and significant impact on price. In particular, ten percentage point increase in operating rate in the previous month will increase the price by 2~3%, a 6.2-9.3 dollar increase evaluated at the average price. It seems that as the operating rate gets higher, buyers are concerned about future supply and thus buy even more, which drives up the price. However the market concentration does not show a statistically significant effect on price. This finding suggests that very little market power exists in linerboard industry. The continued merger and acquisition activities in the linerboard industry have not shown any effects on price. This result is not surprising because the concentration level in the linerboard industry is not particularly high and thus may not result in market power. Given the high transportation cost, regional market power may exist if concentration in some regions is much higher. Because of data limitations, however, we are unable to investigate this issue.

Some existing studies find that consolidation has increased price-cost margins in the pulp and paper industry. Combining with findings in this study, it is possible that industry consolidation may have helped to reduced costs when concentration level is medium. However, we are unable to discern the extent to which consolidation has lowered cost in the linerboard industry. We leave it for future work.

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Figure 1. Real Price and Demand for Linerboard, 1982-1999

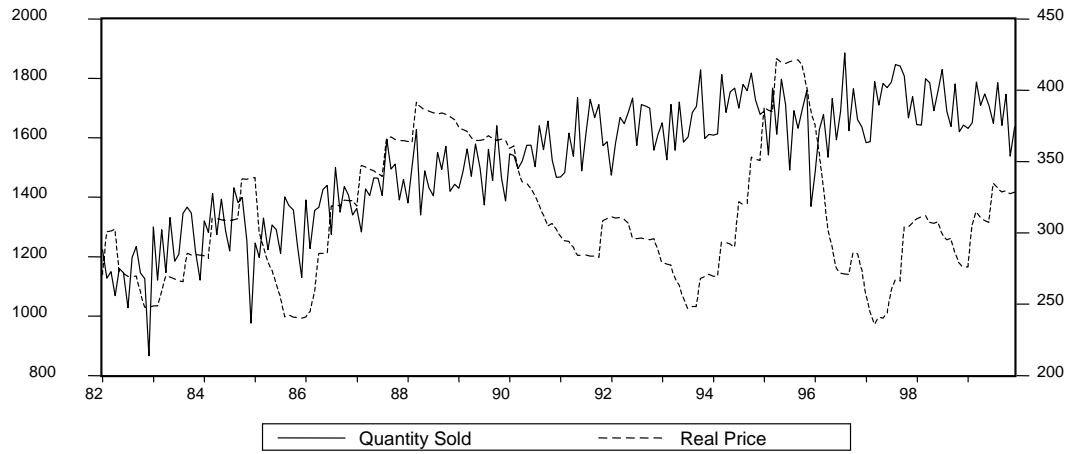


Table 1. Descriptive Statistics

<b>Variables</b>	<b>Description</b>	<b>Mean</b>	<b>STDV</b>	<b>Minimum</b>	<b>Maximum</b>
Linerboard consumption	U.S. linerboard monthly consumptions, in thousand short tons	1518.41	201.66	866.2	1885.2
Linerboard Price	Real price of #42 unbleached kraft linerboard per short ton, with 1982 as base year	310.97	45.21	236.03	421.97
Substitute Price	Real producer price indices of polypropylene resins with 1982 as base year	105.73	15.04	65.09	137.27
Production Index	Total U.S. industrial production indices	134.36	23.13	95.31	188.03
Pulpwood Price	Real producer price indices of pulpwood with 1982 as base year	85.19	6.16	69.60	104.44
Energy Price	Real producer price indices of electricity with 1982 as base year	105.88	4.68	96.29	117.95
Wage Rate	Real average weekly earnings of production workers in the U.S. paperboard mills	613.48	56.40	462.64	750.62
Concentration Ratio	The output share of top four companies	33.39	1.52	30.12	38.84
Operating Rate	Operating rate for unbleached Kraft paperboard	94.18	4.55	73.8	103.4
Unemployment rate	Unemployment rate of the United States	6.42	1.58	3.7	11.4

Table 2. Price and Demand 2SLS Estimates

<b>Variables/Models</b>	<b>1</b>	<b>2</b>	<b>3</b>
<b>Price Function/Linerboard Price</b>			
Linerboard Consumption	0.12** (0.06)	0.15 (0.18)	0.08 (0.07)
Pulpwood Price	0.18* (0.10)	0.32** (0.14)	0.25** (0.12)
Wage Rate	0.12 (0.09)	-0.03 (0.13)	0.02 (0.12)
Energy Price	-0.04 (0.08)	-0.08 (0.22)	-0.05 (0.08)
Lagged price	0.84*** (0.03)	0.83*** (0.03)	0.82*** (0.03)
Unemployment rate	-	-	-0.008 (0.006)
F-Statistics for overidentification	1.51 [0.21]	1.24 [0.30]	1.03 [0.38]
<b>Demand Functions/Linerboard Consumption</b>			
Linerboard Price	-0.16*** (0.06)	-0.12** (0.05)	-0.18*** (0.06)
Production Index	0.74*** (0.17)	0.68** (0.29)	0.61*** (0.19)
Substitute Price	0.14* (0.07)	0.12* (0.07)	0.14* (0.07)
Lagged Sales	-0.11* (0.06)	-0.12* (0.07)	-0.13** (0.06)
Lagged 12 <sup>th</sup> Sales	0.49*** (0.06)	0.19*** (0.07)	0.49*** (0.06)
Unemployment rate	-	-	-0.01 (0.009)
F-Statistics for overidentification	0.24 [0.87]	2.48 [0.06]	0.66 [0.58]

Note: 1. \*, \*\*, \*\*\* indicates significance at 0.10, 0.05 and 0.01 level, respectively.

2. The constant and the coefficients of seasonal and yearly dummies are not reported.

3. Model 1 and 3 include only yearly dummies, while Model 2 includes both yearly and seasonal dummies.

Table 3. Price and Demand 2SLS Estimates

Variables/Models	4	5	6	7	8
<b>Price Function/Linerboard Price</b>					
Linerboard Consumption	0.19 (0.17)	0.18 (0.18)	0.23 (0.18)	0.10 (0.07)	0.09 (0.07)
Pulpwood Price	0.40*** (0.14)	0.33** (0.14)	0.43*** (0.15)	0.37*** (0.13)	0.38*** (0.13)
Wage Rate	-0.12 (0.13)	-0.01 (0.14)	-0.10 (0.14)	0.04 (0.12)	0.05 (0.12)
Energy Price	-0.01 (0.22)	-0.07 (0.23)	-0.002 (0.22)	-0.09 (0.08)	-0.07 (0.08)
Lagged price	0.81*** (0.03)	0.84*** (0.04)	0.82*** (0.04)	0.81*** (0.03)	0.80*** (0.04)
Operating Rate	0.002*** (0.0007)	-	0.003*** (0.0007)	0.002*** (0.0007)	0.002*** (0.0007)
Concentration Ratio (CR)	-	0.003 (0.004)	0.005 (0.004)	0.006 (0.004)	0.015 (0.012)
Unemployment rate	-	-	-	-0.005 (0.006)	0.06 (0.08)
CR*Unemployment	-	-	-	-	-0.002 (0.002)
F-Statistics for overidentification	0.16 [0.92]	1.51 [0.21]	0.25 [0.86]	0.43 [0.74]	0.35 [0.79]
<b>Demand Function/Linerboard Consumption</b>					
Linerboard Price	-0.12** (0.05)	-0.12** (0.05)	-0.12** (0.05)	-0.17*** (0.06)	-0.17*** (0.06)
Production Index	0.68** (0.29)	0.68** (0.29)	0.68** (0.29)	0.61*** (0.19)	0.61*** (0.19)
Substitute Price	0.12* (0.07)	0.12* (0.07)	0.12* (0.07)	0.13* (0.07)	0.13* (0.07)
Lagged Sales	-0.12* (0.07)	-0.12* (0.07)	-0.12** (0.07)	-0.13** (0.06)	-0.13** (0.06)
Lagged 12 <sup>th</sup> Sales	0.19*** (0.07)	0.19*** (0.07)	0.19*** (0.07)	0.49*** (0.06)	0.49*** (0.06)
Unemployment rate	-	-	-	-0.01 (0.01)	-0.01 (0.01)
F-Statistics for overidentification	1.87 [0.12]	1.85 [0.12]	1.49 [0.20]	1.18 [0.32]	1.13 [0.35]

Note: 1. \*, \*\*, \*\*\* indicates significance at 0.10, 0.05 and 0.01 level, respectively.

2. The constant and the coefficients of seasonal and yearly dummies are not reported.

3. Model 4, 5, and 6 include both yearly and seasonal dummies, while Model 7 and 8 include only yearly dummies.