TWO ESSAYS ON THE DEMAND FOR AND SUPPLY OF PAPER AND PAPERBOARD PRODUCTS

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TWO ESSAYS ON THE DEMAND FOR AND SUPPLY OF PAPER AND PAPERBOARD PRODUCTS

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DEDICATION

I would like to dedicate this work to my parents and my brother

for their love, support, patience, and encouragement.

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LIST OF ABBREVIATIONS

2SLS	Two Stage Least Squares Estimation
ADF	Augmented Dickey-Fuller Unit Root Test
AFPA	American Forest & Paper Association
C.I.F.	Costs, Insurance, and Shipping costs
FDI	Foreign Direct Investment
FPL	Forest Products Laboratory
FTC	Federal Trade Commission
GDP	Gross Domestic Product
IV	Instrumental Variable Estimation
LR	Likelihood Ratio
OLS	Ordinary Least Squares Estimation
PPI	Producer Price Index
SOEs	State-owned Enterprises
VAR	Vector Autoregressive Model
VEC	Vector Error Correction Model
WTO	World Trade Organization

SUMMARY

This thesis compiles two papers on the structure models of the paper and paperboard industry. The first part of this thesis examines the relationship between economic transition and demand pattern in China. The economic transition in China poses new questions in studying product demand. In this study, we investigate the demand pattern and structural changes during the economic transformation using annual data from the paper and paperboard industry in China. Instrumental variable estimations as well as cointegration analysis and error-correction models are applied to the analysis. Our results show that in the early stages of economic reform, the income elasticity of demand for domestically made paper and paperboard products is about 1; and the own-price elasticity and the cross price elasticity with respect to world market price are both statistically insignificant. After 1992, the own and cross price elasticity increases, respectively, to -0.69 (in absolute value) and .59. With respect to import demands, the estimated income elasticity is not statistically different from 1.0 and the cross-price elasticity with respect to the domestic price is statistically insignificant; the own-price elasticity, on the other hand, increases from -0.60 to -0.50 before and after 1992, respectively. The results indicate that imports are substitutes for domestically made paper and paperboard products, but the reverse is not true, and there was a considerable structural change in the demand during the course of China's economic transition.

In the second part, we develop a two equation structural model to identify the factors determining the U.S. linerboard demand and supply. It is well known that demand and price are determined in a simultaneous system, which, if not properly addressed, will lead to biased and inconsistent results. This study utilizes monthly data ranging from

1982 to 1999, and uses a simultaneous equations model to estimate and examine the key factors influencing the supply and demand. The empirical results are quite robust across different model specification. The price elasticity of linerboard demand ranges from -0.07 to -0.14 and is highly significant. The income elasticity lies in the range of 0.17 to 0.25. On the price side, the sale of linerboard and material cost are the two factors that have significant impact on the price. Of especial interest in this paper is to test the existence of market power in the U.S. linerboard industry. Due to merger activities, the U.S. linerboard industry has become more concentrated during the past decade, which raises concerns on market power and price manipulation. Our results however show that there exists no market power in the U.S. linerboard industry. Almost all coefficients before the mark-up factors are insignificant though of expected sign.

PART I
ECONOMIC TRANSITION AND DEMAND PATTERN: EVIDENCE FROM CHINA'S PAPER AND PAPERBOARD INDUSTRY

1. Introduction

China's economic transition since 1979 is characterized by rapid economic growth, gradual transformation into a market system, and increasing integration into the world economy. The complex economic dynamics during the transition period affects every aspect of the economic system, including industry demand structure. Understanding the demand for a particular industry is important for policy makers and for the industry stakeholders; as an emerging international market, China is also of especial interest to foreign producers and investors who are ready to tap into the Chinese market.

Moreover, the economic transition and market reforms may add new features to industry demand, and thus poses new questions in studying the demand structure. Over the period of 1979-2001, continuing economic growth and economic reforms have dramatically changed the Chinese economy, providing an opportunity to investigate the demand dynamics during the economic transition.

This study investigates China's demand for paper and paperboard products. The paper and paperboard industry represents Chinese traditional industries, which underwent dramatic and challenging transitions. A common feature of a traditional industry in China is that most firms in this industry were state-owned or other publicly owned and thus operated under the government planning system that did not use profits or return on investment as a metric for success. The economic reforms forced state-owned enterprises to adopt more market oriented approaches and are increasingly employing market-related criteria to evaluate the success of the enterprise. As a result, China's economic transition requires reforming existing industry structures and operating mechanisms. This change is having a greater impact on traditional industries (with inefficient organizational structures and high sunk costs) relative to ‘new economy’ industries, such as information technology (IT), which suffer considerably less from these 'legacy costs'. Moreover, traditional industries are facing increasing competition from international producers as China gradually opens its markets. Thus, the combined effects of increasing international competition and market reforms can have serious implications for traditional industries as they seek to adapt their operations and compete for market share in a globally competitive marketplace.

At the same time, China possesses a huge market potential for paper and paperboard products. Chinese total paper and paperboard consumption is currently ranked second in the world, only behind the U.S. The consumption of paper and paperboard products in 2001 reached 42.6 million metric tons, increasing at an average annual rate of 10.38% over the last 20 years.[1] By comparison, the average growth rate of the U.S. paper and paperboard consumption over the same period is 1.85%.[2] China’s imports of paper and paperboard products grew at an average annual rate of 12.7% for the period 1979-2000, and the share of imports in the consumption increased from 9% to 17% for the same period. In 2001, China imported 5.57 million tons of paper and paperboard products, almost double the amount in 1995.

Yet, in comparison with the worldwide average of 53.8 kg and the U.S. average of 331.7 kg, China's per capita paper and paperboard consumption remains very low, at 28.4 kg in 2000. Therefore, as the Chinese economy grows, spurred on by continuing

[1] Consumption, import and capacity are defined in metric tons throughout this study.
[2] The statistics source is *FAO Statistical Databases*.

economic reforms and an increasingly literate population, the demand for paper and paperboard products will increase rapidly. In addition, with the entry into World Trade Organization (WTO), China import tariffs are expected to fall from 12-15% to 5% for most paper and paperboard grades over the next few year. Overall, there is every expectation that China will be one of the major markets for international pulp and paper producers.[3]

Currently China's small-scale mills and outdated technologies limit its ability to satisfy the growing demand. Its capacity and output are scattered among numerous small mills. On average, Chinese paper mills produce less than 6,500 tons/year, while the world average is over 40,000 tons/year and the average in developed countries is well above 100,000 tons/year. Only 44 of China's 4748 mills produce more than 10,000 tons per year and only a handful of them produce products of international quality. Due to the highly capital-intensive nature of the paper and paperboard production, China needs a significant amount of investments to modernize its pulp and paper industry. A number of international companies have invested in China in recent years, including Indonesia-based Asia Pulp & Paper Co., UPM-Kymmene Co. (Finnish), and Stora Enso (Finnish-Swedish).[4] And at least 43 new projects have been scheduled in China's paper and paperboard industry for the period of 2002-2004, adding a new capacity of nearly 6 million tons per year to the industry in the near future.

Despite the worldwide interest in this burgeoning industry, there is no existing study on the demand for paper and paperboard products in China, although there are a

[3] "China and Taiwan Lower Import Tariffs for Pulp, Paper and Board", available at: http://www.paperloop.com.
[4] In March 1999, Singapore based Asia Pacific Resources International Holdings began operating a 350,000 ton/yr uncoated woodfree paper machine at Changshu, China; and Asia Pulp & Paper Co. started two woodfree paper machines at its Dagang mill in China.

number of studies for other countries. Buongiorno and Kang (1982) investigated short- and long-run elasticities of U.S. demand for paper and paperboard. Hetemäki and Obersteiner (2002) examines the demand for newsprint in the United States for the period 1971 to 2000. Chas-Amil and Buongiorno (2000) used panel data to estimate paper and paperboard demands for 14 European Union countries. And Simangunsong and Buongiorno (2001) used panel data on 62 countries during the period 1973 – 1997 to estimate the price and income elasticities for nine groups of forest products

In this study, we investigate the demand pattern for paper and paperboard products in China with time-series data from 1979 to 2001, focusing on the structural changes caused by economic reform and integration into the world market. The total demand for paper and paperboard products consists of two parts: domestic products and imports. The domestically produced paper and paperboard products are generally low quality products. In particular, over 80% of the pulp produced in China is made from bamboo, reed, rice straw, wheat straw and other non-wood sources, which yield lower quality products relative to those produced from wood pulp. Based on the information from China Paper Association, in 2000, 80% of China's paper and paperboard products are low-quality and medium-quality grades, requiring China to rely on imports for high quality grades.[5]

Given the quality difference between the domestic product and imports, simply pooling the domestic and import demands imposes restrictions of homogeneous income and price elasticities on the two different demand functions. Thus, we extend our theoretical model on demand to include inputs, and estimate the two demand functions

[5] "The Tenth Five-year Plan of China's Paper and Paperboard Industry" (in Chinese), China Paper Association, April 12, 2001, available at: http://www.cppi.com.cn/zylt/a18.htm.

separately, i.e., the demand for domestic products and the demand for imports. Following traditional approach to demand estimation, we first estimate demand functions using an instrumental variable estimator, and test for a structural change in demand. Second, in order to address the concern for nonstationarity of the variables in the demand function, cointegration analysis and error-correction models are applied to the demand functions.

The paper is organized as follows. In Section 2, we outline a theoretical framework for the demand structure and develop empirical models. Section 3 briefly describes the data. Section 4 discusses the results based on instrumental estimations; and Section 5 reports the results based on co-integration analysis and error correction models. Section 6 concludes.

2. A Simple Demand Model

Since paper and paperboard products mostly serve as inputs in many industries, in the classical approaches, the demand is derived from the demand for final products.[6] Paper and paperboard product enters the production function as intermediate good. During the course of economic transition, China has gradually moved to a market-oriented economy, both domestically and internationally. To capture such institutional changes, we generalized the commonly used production function to treat imported paper and paperboard products as a separate input. It is very likely that international markets play an increasing role in China's domestic demands. In addition, due to existing quality differences, domestic paper and paperboard products may not be used as substitutes for imports.

[6] According to "The Tenth Five-year Plan of China's Paper and Paperboard Industry", well above 80% of total paper and paperboard products in China are employed as inputs for other industries such as publishing, package and printing, and less than 20% are directly consumed by consumers.

Therefore, as commonly used in other studies (Chas-Amil and Buongiorno 2000, Simangunsong and Buongiorno 2001), we assume Cobb-Douglas production function as below

$$Y_t = a\, D_t^{*b} \cdot I_t^{*c} \cdot X_t^{d}, \tag{1}$$

where Y_t is the production function of final products, D_t^* reflects paper and paperboard inputs made domestically, I_t^* is the imported paper and paperboard, X_t is a vector of other inputs, a is an index for the state of technology, and b, c, and d are positive parameters.[7] Total cost C_t is represented by:

$$C_t = D_t^* P_t^D + I_t^* P_t^I + X_t P_t^X, \tag{2}$$

where P_t^D, P_t^I, and P_t^X are the paper and paperboard price, imported paper and paperboard price, and the prices of other inputs, respectively. Minimizing cost with regard to D_t^*, I_t^*, and X_t, subject to the production function, we obtain the demand function for domestic paper and paperboard and for imports:

$$D_t^* = F(Y_t, P_t^D, P_t^I, P_t^X) = \delta_0 Y_t^{\delta_1} \left(\frac{P_t^D}{P_t^X}\right)^{\delta_2} \left(\frac{P_t^I}{P_t^X}\right)^{\delta_3} \tag{3}$$

$$I_t^* = F(Y_t, P_t^I, P_t^D, P_t^X) = \delta_0 Y_t^{\tau_1} \left(\frac{P_t^I}{P_t^X}\right)^{\tau_2} \left(\frac{P_t^D}{P_t^X}\right)^{\tau_3} \tag{4}$$

where $\delta_1 = \tau_1 = 1/(b+c+d)$, $\delta_2 = -(c+d)/(b+c+d)$, $\delta_3 = c/(b+c+d)$, $\tau_2 = -(b+d)/(b+c+d)$, $\tau_3 = b/(b+c+d)$.

Equations (1) and (2) represent a static demand model assuming that equilibrium is achieved within time period t (one year for this analysis), and D_t^* and I_t^* is the equilibrium consumption for paper and paperboard products. If the adjustment takes

[7] It is possible to use a more sophisticated demand function such as AIDS (see Deaton and Muellbauer, 1980). However, this type of functions generally requires additional data information such as cost shares, which is unavailable in our data. More importantly, as one of the first studies on demand for paper/board in China, we adopt the simpler approach in order to focus on the structural changes in demand as a result of economic transition.

longer time, there will be a dynamic adjustment process. In order to allow for such possibility, we assume that during time period t, the adjustment process can be represented by the following model:

$$\frac{D_t}{D_{t-1}} = \left(\frac{D_t^*}{D_{t-1}}\right)^{\alpha_1} \qquad \text{or} \qquad \frac{I_t}{I_{t-1}} = \left(\frac{I_t^*}{I_{t-1}}\right)^{\alpha_2} \tag{5}$$

where α is the speed of adjustment, $0 \leq \alpha \leq 1$, and D_{t-1} is consumption in the previous time period. Substituting equation (5) in equations (3) and (4), we obtain a dynamic demand model:

$$D_t = \gamma_0 Y_t^{\beta_1} \left(\frac{P_t^D}{P_t^X}\right)^{\beta_2} \left(\frac{P_t^I}{P_t^X}\right)^{\beta_3} D_{t-1}^{\beta_4} \tag{6}$$

$$I_t = \varphi_0 Y_t^{\lambda_1} \left(\frac{P_t^I}{P_t^X}\right)^{\lambda_2} \left(\frac{P_t^D}{P_t^X}\right)^{\lambda_3} I_{t-1}^{\lambda_4} \tag{7}$$

where $\gamma_0 = \delta_0^{\alpha_1}$, $ß_1= \delta_1\alpha_1$, $ß_2= \delta_2\alpha_1$, $ß_3= \delta_3\alpha_1$, $ß_4= 1- \alpha_1$, $\varphi_0 = \delta_0^{\alpha_2}$, $\lambda_1 = \tau_1\alpha_2$, $\lambda_2 = \tau_2\alpha_2$, $\lambda_3 = \tau_3\alpha_2$, and $\lambda_4 = 1- \alpha_2$.

Taking logarithms of equation (6) and (7) yields the following empirical demand functions for domestic products and for imports:

$$\ln D_t = ß_0 + ß_1 \ln Y_t + ß_2 \ln P_t + ß_3 \ln PA_t + ß_4 \ln D_{t-1} + u_t \tag{8}$$

$$\ln I_t = \lambda_0 + \lambda_1 \ln Y_t + \lambda_2 \ln PA_t + \lambda_3 \ln P_t + \lambda_4 \ln D_{t-1} + \varepsilon_t \tag{9}$$

where D_t is the domestic demand in year t, I_t is the import demand in year t, Y_t is represented by real gross domestic product (GDP), P_t is the real domestic price index of paper and paperboard, PA_t is the real international price index of paper and paperboard, and both u_t and ε_t are disturbance terms. In the domestic demand function, $ß_1$, $ß_2$, and $ß_3$ represents, respectively, the income elasticity, own price elasticity, and cross price elasticity of domestic demand; in the import demand function, λ_1, λ_2, and λ_3 are the income elasticity, own price elasticity, and cross price elasticity of import demand, respectively.

The above models do not control for possible structural changes caused by China’s economic transition. The transition can be characterized by a rising degree of market-oriented mechanisms and an increasing integration into the world market, which will affect the demand structure for paper and paperboard products. For example, state-owned enterprises (SOEs) used to operate under a state planning system. They were not responsible for profits and losses. In this situation, SOEs may not respond to price signal at all. The reforms have forced most SOEs to enter the market system. In order to survive in competitive markets, SOEs have to be more sensitive to input prices. On the other hand, during the economic transition, non-state-owned enterprises represent an increasing share of the economy. Like other capitalist firms, these enterprises are sensitive to input costs. Therefore, as the economic transition continues, the economy should become more responsive to price changes and the demand should be more price elastic. Similarly, the greater access to international markets may also influence the demand pattern for imported paper and paperboard products.

As a result, these institutional factors must be taken into account in estimating China's demands. Prior to 1992, the Chinese economy was largely a command economy under the old planning system. Although China was gradually reforming after 1978, the aggregate demand for paper and paperboard was mainly determined by the government. The economic reforms accelerated after 1992, subsequent to Deng Xiaoping’s dramatic political campaign visit to south China. Since that time, China has moved more quickly towards an open economy market system. The share of state-owned enterprises in gross industrial output value decreased from 77.63% in 1978 to 46.95% in 1993 and 23.53% in 2000. In order to capture this structural effect in the empirical model, we define a dummy variable (R_t) that equals 0 prior to 1993 and 1 for 1993 and after. It can be used to capture the net effects of economic reforms on the demand structure, which include their effects on income elasticity and price elasticities.

3. The Data

We use annual data from 1979-2001 for this analysis. The demand for domestic paper and paperboard products is measured by total domestic output minus exports and the demand for imports is measured by actual imports. The statistical sources for the analysis included '*China Statistical Yearbook 2002',* the *'Almanac of Paper Industry of China 1999',* the World Bank Development Indicator Database, and the US Bureau of Labor Statistics. Following previous studies, China's real GDP is used as a proxy for economic activity. Nominal GDP is converted to real GDP, with 1979 as base year. We use the ex-factory price indices to measure the domestic real price for paper and paperboard, deflated by the GDP deflators based on 1979 purchasing power.[8]

When we measure the price for imported paper and paperboard products, three factors need to be considered. One is the shipping cost, which has dropped considerably during this 23-year period. The second factor is the exchange rate. The official exchange rate of Chinese yuan varied from 1.55 to 8.28 during the period of this analysis. The

[8] Chinese State Statistic Bureau gives the following definition: Ex-factory Price Index of Industry Products reflects the change in general ex-factory prices of all industrial products, including sales of industrial products to commercial enterprises, foreign trade sector, materials supplying and distribution sectors as well as sales of production means to industry and other sectors and sales of consumers goods to residents.

variation will significantly affect the cost of imported paper and paperboard. The last factor is the tariff.

In order to control for these factors, we fist calculate the import price based on US dollars. In particular, for all grades of paper and paperboard, the Chinese statistics reported both the imported value in US dollars and the total imported volume in tons. The total value of imported paper and paperboard is calculated on C.I.F. base (i.e., costs, insurance, and shipping costs).[9] Thus the import price is calculated by dividing the value of paper and paperboard imports by the volume of imported paper and paperboard. The import price is converted into Chinese currency by multiplying the calculated import price in US dollars with official exchange rates. The *China Statistical Yearbook* does not contain the values of imports for 1979 and 1980. These two missing observations are extrapolated by regressing import price on the U.S. producer price index (PPI) for all grades of paper and paperboard (products excluding converted and building paper).[10] Finally, the calculated import price is converted into a real price using Chinese GDP deflator, with 1979 as the base year. The adjusted import price controls for shipping costs and exchange rate but it may not capture the effect of tariffs. Unfortunately, such information is not available. Since the period covered in this study is mostly before China's joining the WTO, the change in tariff for paper and paperboard product is not expected to be dramatic, and thus we assume that the effect of tariff on import price is relatively small. Descriptive statistics are reported in Table 1.

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[9] The C.I.F. price is the purchaser's price that would be paid by an importer taking delivery of the good at his own frontier, before paying any import duty or other tax levied at the frontier.

[10] Based on US Bureau of Labor Statistic, the Producer Price Index (PPI) measures the average change over time in the selling prices received by domestic producers for their output. The prices included in the PPI are from the first commercial transaction for many products and some services.

Table 1. Descriptive Statistics

Variable	Variable Description	Mean	Standard Deviation	Minimum Value	Maximum Value
Domestic Demand	Paper and paperboard output minus exports, in million metric tons	15.62	8.88	4.77	37.09
GDP	Real gross domestic product, in 100 million Yuan	13432.77	8131.61	4038.20	29718.47
Domestic Price	Real ex-factory price indices in China	107.04	11.52	91.03	129.13
Import Price	Real prices of paper and paperboard imported.	203.53	40.04	137.05	278.39
Import Demand	Imports of paper and paperboard into China, in million metric tons	2.44	2.11	0.49	6.52
R_t	Dummy=1 for 1993 and subsequent years, zero otherwise				

4. Instrumental Variable Estimation

In estimating the demand equation, we first apply the traditional regression analysis based on the structural model discussed in the above section. Since demand and price are jointly determined in the market, price should be endogenous in the demand function. Existing studies of paper demand treat this issue differently in the estimation. For example, Chas-Amil and Buongiorno (2000) used unit values of imports and/or exports to construct price indices. They argue that such a price index is exogenous in the demand function because the demand in each country is too small to affect the international price. Hetemäki and Obersteiner (2002) investigated U.S. newsprint demand, and they addressed the possible simultaneity between newsprint consumption and prices using a vector autoregression model (VAR).

In this study, we use instrumental variable (IV) estimation to account for price endogeneity.[11] Given the data limitations, we follow the traditional practice in time series analysis by using the previous price as instrument for the current price. Presumably, the current demand is not determined simultaneously with the previous price and thus can be used as instrument. The import price is mainly determined in the international market, and hence it is treated as exogenous because Chinese imports of paper and paperboard products are still relatively small in the world market and do not affect the world price.

4.1 The Demand for Domestic Paper and Paperboard Products

In preliminary work, we applied ordinary least squares (OLS) to estimate the demand function for domestic paper and paperboard products.[12] We then use instrumental variable estimation to estimate the demand function. The estimation results from two-stage-least-squares (2SLS) are reported in Table 2. Given the possibility of serial correlation in the regression error, we tested each model for serial correlation.[13] The test result on the correlation coefficient is also reported in the table. Based on the results, we found no evidence of serial correlation. This result is not surprising because we are estimating a dynamic model using annual data. As discussed below, the adjustment of paper and paperboard demand to its equilibrium level appears to be

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[11] Since the consumption for paper product is part of GDP, it is also possible that GDP is endogenous. However, paper and paperboard consumption are generally a very small portion of the GDP, comprising, for example, only 1.78% in China in 2000 (*China Statistical Yearbook 2001*). Thus, the endogeneity for GDP is not considered here. This issue will be addressed in VAR model estimation in next section.

[12] The estimated short run income elasticity was 0.52 and statistically significant at 0.05 level; the estimated price elasticity was 0.39 prior to 1993 and -0.11 after 1993, but was not statistically significant; the short run cross price elasticity had the expected sign (-0.05 prior to 1993, and 0.38 after 1993) but was insignificant. OLS results suggest that there was a structural shift in the growth pattern of China's demand for paper and paperboard after 1993.

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

completed in the year (for most models, the lagged dependent variable is not significant). Therefore, the demand models estimated are "dynamically complete" with one lag of the dependent variable, and thus the regression error should not be serial correlated.

Table 2. Demand for Domestic Paper and Paperboard in China by IV estimation

Variable	Domestic Demand 1	Domestic Demand 2	Import Demand 3
Constant	4.42 (6.86)	-8.11*** (2.74)	-9.30* (5.11)
GDP	0.19 (0.32)	1.01*** (0.20)	0.89** (0.38)
Domestic Price	-1.46 (1.14)	0.35 (0.90)	0.96 (1.64)
Import Price	0.13 (0.19)	-0.07 (0.25)	-0.60* (0.30)
Lagged Domestic Demand	0.98** (0.45)		
Lagged Import Demand			
Reform dummy * Domestic Price		-0.69* (0.39)	
Reform dummy * Import Price		0.59* (0.34)	0.10* (0.05)
Test for autocorrelation ρ	0.41 (0.68)	0.52 (0.33)	0.08 (0.31)

Note:
*, **, *** = significant at 0.10, 0.05 and 0.01 level.
ρ = coefficient of AR(1) serial correlation.

In Table 2, Model 1 is the base model and does not control for institutional changes in China caused by the economic transition. In this model, only the lagged demand variable is statistically significant; while other variables such as GDP and prices are not. In order to control for possible structural changes in the demand, we interact the economic transition dummy with prices and GDP. In different specifications, the interaction between the dummy and GDP never appears statistically significant. This is possible because the transition dummy mainly captures the progress of moving to a market system. In addition, it is likely that the relationship between the demand for all paper and paperboard products and GDP has not undergone an enough significant change in these two time periods.[14]

After including structural change terms, the lagged demand variable becomes insignificant. As discussed in the theoretical model, lagged demand controls for the process of demand adjustment toward equilibrium. If the demand adjustment is complete within a year, which is possible for paper and paperboard, including lagged demand as an explanatory variable is not necessary. Since it is statistically insignificant and to save degrees of freedom, we do not include lagged demand in the final model.

Model 2 shows the final specification of the domestic demand model. Based on the results, GDP has a significant impact on the demand for domestic paper and paperboard products, with a unitary income elasticity (i.e., the demand grows at the same speed as GDP). A unitary find for the income elasticity of demand is higher than that found for developed countries. For example, depending upon the type of paper and paperboard grades, Baudin and Lundberg (1987) reported income elasticities ranging from 0.54 to 0.66 for all major consuming countries for the period 1961-81. Chas-Amil and Buongiorno (2000) found income elasticities ranging from 0.18 to 0.39 for the European Union.[15]

Given that China is still at a relatively low level of economic development with a majority of traditional industry, the higher income elasticity of demand is plausible and consistent with the finding that the demand for paper and paperboard becomes less

[14] Some studies find that the demand response to GDP has changed for some specific grades of paper products, such as newsprints and printing papers, in some countries due to the development IT technology (Hetemäki and Obersteiner, 2002).

[15] Chas-Amil and Buongiorno (2000) also provided elasticities for the individual countries. The estimated income elasticity ranged from 0.15 in Portugal to 0.64 in Denmark.

income elastic as a country's income increases. For instance, Baudin and Lundberg (1987) found that the income elasticity was highest in the low income groups (per capita GDP under $2000). In the study of Buongiorno (1978), in which 43 countries were divided into low-income countries and high-income countries, the author found that, with the exception of printing and writing paper, the income elasticities are higher in low-income countries.

Interestingly, both the domestic price elasticity and the international price elasticity are statistically insignificant before 1993. As discussed in the above section, this is possible because the Chinese economy was just beginning to open its markets. SOEs still produced a large portion of the product and they were not yet transformed into market oriented enterprises. Therefore, to a large extent, SOEs did not have to meet market investment criteria for continued operation. As a result, it is not surprising that demand was relatively insensitive to price changes, consistent with the empirical finding which fails to reject the hypothesis that the own-price elasticity of demand is zero.

This situation has changed as China deepening its economic reforms. Most SOEs have been transformed to a so-called modern enterprise system and are now required to satisfy market criteria for continued operations and, accordingly, implying that demand will be more sensitive to price changes. From the results, the own-price elasticity after 1993 is -0.69 and statistically significant at the 10% level. Notwithstanding this, demand is price inelastic, suggesting that few substitutes are available, although more price sensitive than the (-0.48, -0.31) and (-0.89, -0.30) range reported by Baudin and Lundberg (1987) and Chas-Amil and Buongiorno (2000), respectively.

The response of the demand for domestic paper and paperboard products to international price changes is positive and significant at about the 10% level after 1993. The cross-price elasticity is 0.59, indicating that the demand for domestic paper and paperboard products is affected by the international markets as China becomes more integrated into the world market. If the international price is high, the demand for domestic products increases; otherwise, China increases imports and reduces demand for domestically produced products. Therefore, imports appear to be a substitute for domestically made products. Clearly, the international markets can offer almost all types of paper and paperboard products needed in China, and these products can certainly substitute for the products that China produces domestically. As expected, the demand for domestic products is more responsive to own price change than to international price change.

4.2 The Demand for Imported Paper and Paperboard Products

China's imports of paper and paperboard products have increased rapidly. The share of imports in total paper and paperboard consumption, for example, has grown from 9% in 1979 to 17% in 2000. As China becomes a major player in the international paper and paperboard market, its demand for imports will have an increasing impact on the world market. In order to further investigate the integration of the Chinese market into the world market and the relationship between the demands for domestic products and imports, we also estimate the demand function for imports.

Since imports account for almost 20% of the total consumption in recent years, it is possible that the domestic price is affected by the amount of total imports, and thus is considered endogenous. Hence, we estimate the demand using IV estimation with lagged domestic price as an instrument. Since it is unlikely that Chinese imports affected the world price for the period studied, we assume that the international price is exogenous.

The results are reported in Table 2. As in the discussion of the specification for domestic demand estimation, we do not include lagged dependent variable because it is insignificant. The demand elasticity with respect to GDP is 0.89 and is significant at the 5% level (there is no significant change in the two periods). We cannot reject that the income elasticity is 1. Such a demand pattern suggests that as the Chinese economy continues to grow, the demand for imports will also grow rapidly, almost at the same pace as the economy, and China will be an important potential market for international producers. The income elasticities of demand for both domestic products and imports appear to have unitary elasticity. This result is somewhat surprising because if imports are mostly high quality products, thus like luxury good, the income elasticity should be higher than that for domestic products. A possible explanation is that some trade barriers (especially administrative barriers) may exist and have depressed the demand. Another explanation would be that, as discussed in Section 1, the demand is also affected by increasing the amount of foreign direct investment (FDI) to produce high quality products in China.

Import demands are also sensitive to changes in the international price, with price elasticity equal to -0.60. The demand is price inelastic, and is in the same range of price elasticity for domestic demand. The inelastic response to price changes also suggests that relatively few substitutes are available for imported paper and paperboard products as a whole. This observation is also confirmed by the insignificant cross-price elasticity. The import demand does not seem to be affected by the domestic price, although the demand for domestic products is responsive to international price as discussed above. Therefore, these results are consistent with the notion that imports are a substitute for domestically produced paper and paperboard produces but that domestically produced products are not a substitute for imports. Such a difference can almost certainly be attributed to quality differences, and thus the two demand functions are in fact consistent with each other.

As the economic reforms deepen, the own-price elasticity appears to drop slightly. In other words, the import demand response to own-price becomes even less price elastic in the second period starting from 1993 (the difference of 0.10 is significant at the 10% level). One explanation is that as China's ability to produce higher quality products (for example, due to FDI), the imports focuses increasingly on some specific grades of products. Thus, demand becomes less elastic. If this is case, we may expect that the income elasticity of imports for high quality imports will increase as the economic transition continues. Yet we cannot discern this effect in our model, probably because the effect has not fully materialized in our period of study.[16]

5. Vector Error Correction Model Estimation

The traditional regression analysis provides estimates of various elasticities, and can conveniently test the possible structural change in the demand. One particular concern for the regression analysis using time series data is the possibility of nonstationarity of the variables. Nonstationarity (for example, caused by unit root) may result in spurious regression caused by unreliable t-statistics. To explore this, we analyze

[16] It is likely that the import demand structure will change with China's joining the WTO in 2000. With the availability of future data, the WTO effect can be evaluated.

the stationarity property of some time series used in the regression and apply cointegration techniques to study the demand.

Although cointegration analysis has advantages in dealing with non-stationary data, it can only identify long-run relationship and is generally difficult to test structural changes. Moreover, the Chinese economy is evolving as the economic transition continues. It is unclear whether China has reached the long-run equilibrium demand relationship or the stability of such a relationship, especially given the rapid structural changes in the Chinese economy. In this sense, the results from the regression analysis in the section above and the results based on non-stationary time series in this section should be viewed as complementary.

Although most previous studies on paper and paperboard demand have ignored the stationarity issue, a number of other studies have applied techniques for non-stationary data in studying pulp market and paper imports. Sarker (1996) used cointegration analysis to investigate the effects of price, income and other factors on Canadian softwood lumber exports to the United States. Riis (1996) adopted an error correction model to forecast Danish timber price. Alavalapati et al. (1997) investigated the determinants of Canadian pulp price. Laaksonen et al. (1997) estimated short- and long-run export demand for Finnish printing and writing paper in the United Kingdom.

We first employ Augmented Dickey-Fuller (ADF) unit root tests (Dickey and Fuller 1979) for demand, GDP, and domestic price.[17] The results of the ADF test are presented in Table A1 at the appendix (lags are selected based on F-tests and Schwarz criterion). These variables appear to be nonstationary in levels; however, the unit root

[17] The ADF test for the international price gives an insignificant ADF statistic of -1.7 for the level series, and a highly significant statistic of -5.23 for the first differenced series, indicating that the international price is I(1).

hypothesis is rejected for first differences, implying that they are I(1). Based on the ADF test, we conduct cointegration analysis and estimate a vector-error-correction model (VEC) based on Johansen methodology (Johansen 1988, 1991). For a kth order unrestricted VAR model:

$$X_t = \pi_0 + \pi_1 X_{t-1} + \pi_2 X_{t-2} + \cdots + \pi_k X_{t-k} + \varepsilon_t \qquad (10)$$

where X_t is an (n×1) vector of I(1) variables, π_i are (n×n) parameter matrices (i = 1, …, n), k is the lag-length, and $\varepsilon_t \sim iid(0, \sigma^2)$, an error correction representation is,

$$\Delta X_t = \pi_0 + \Pi X_{t-1} + \sum_{i=1}^{k-1} \Gamma_i \Delta X_{t-i} + \varepsilon_t \qquad (11)$$

where Δ is the first difference operator, $\Pi = \sum_{i=1}^{k} \pi_i - I$, $\Gamma_i = -\sum_{j=i+1}^{k} \pi_j$, and I is the identity matrix.

This VEC model is a traditional first difference VAR model plus an error correction term ΠX_{t-1}. The matrix Π contains information on the long-run co-movement of the variables. If r, the rank of Π, is 0 < r < n, we have r cointegrated vectors. A likelihood ratio (LR) test is used to determine the optimum number of lags (Sims 1980).[18] The LR statistic is obtained by estimating the unrestricted and restricted VAR, each with different lags. Due to limited sample size, the unrestricted equation started with lag-length k equal to 4. The test is then conducted sequentially by reducing k one at a time. The results show that the appropriate lag-length in the VAR model is 3, and thus for the VEC model is 2.

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[18] LR = -2 ($\ell_k - \ell_{k+1}$), where ℓ_k is the log likelihood of VAR with lags k. The LR statistic is asymptotically distributed with degrees of freedom χ^2 equal to the number of restriction.

Johansen's maximum likelihood cointegration tests are applied to find the cointegrated series. Johansen's method tests the restrictions imposed by cointegration on the unrestricted VAR. The method entails two tests for the number of cointegrating vectors r: the trace and the maximum eigenvalue tests (see also Hamilton 1994 and Walter 1995 for more discussions). The results are summarized in table A2. The trace test suggests two cointegrating vectors but the maximum eigenvalue test suggests that there is one cointegrating vector. We estimate the cointegration relationship is following:

$$\ln D_t = -7.99 + \underset{(0.03)}{1.01} * \ln Y_t - \underset{(0.66)}{0.22} * \ln P_t + \underset{(0.09)}{0.42} * \ln PA_t \qquad (9)$$

Table 3. The long-run elasticities from IV and Cointegration test

	Long-run elasticities		
	GDP	Domestic Price	Import Price
IV estimates after 1992	1.01***	-0.69*	0.59*
	(0.20)	(0.39)	(0.34)
Johansen's Maximum likelihood	1.01***	-0.23	0.42***
	(0.03)	(0.23)	(0.09)

Note: *, **, *** = significant at 0.10, 0.05 and 0.01 level.

Table 3 lists the elasticities from both the IV estimation (model 2) and the cointegration analysis. The elasticity estimates based on cointegration analysis is in line with that from the IV estimation. The own-price elasticity based on cointegration is lower than the IV estimates for the period after 1992, and it is statistically insignificant. This is because the cointegration analysis does not control for structural change, and thus it pools the two periods before and after 1993 together. It appears that the demand-price relation prior to 1993 dominates such a relationship, and thus the price effect becomes insignificant overall. This is also the case for the cross-price relationship. As for the income elasticity, the IV results do not show any structural change, and the estimated income elasticities based on both approaches are very close to each other.

Table 4. Estimates of the vector error correction model

Dependent Variable: ΔDomestic $Demand_t$		
Regressors	Coefficients	Standard error
Error Correction Term	-1.13	0.18
ΔDomestic $Demand_{t-1}$	0.92	0.20
ΔDomestic $Demand_{t-2}$	1.02	0.21
ΔGDP_{t-1}	-1.61	0.67
ΔGDP_{t-2}	-0.38	0.80
ΔDomestic $Price_{t-1}$	-0.58	0.25
ΔDomestic $Price_{t-2}$	0.19	0.26
ΔImport $Price_{t-1}$	-0.12	0.10
ΔImport $Price_{t-2}$	0.10	0.10
Adj. R^2	0.78	
LM(1)	17.39 [0.36]	
White test	184.93 [0.39]	
Jarque-Bera	38.51 [0.96]	

Note:
Test assumption: linear trends in the data but the cointegration equations have only intercept.
Figures in blanket denote probability value.

Since the cointegration relationship represents a long-run equilibrium, it is desirable to examine the short-run dynamics. Thus, we estimate a VEC model to study the demand adjustment. Based on the results summarized in table 4, the error-correction term in the demand function is -1.13 and significant at 1 percent level. The negative coefficient of error-correction term ensures that the long-run equilibrium is achieved when there was a deviation in the previous period. More specifically, if there is a one percent positive deviation of demand from the long-run equilibrium in last period, the growth rate of demand falls by 1.13 percentage point in current period. Thus the system automatically adjusts to eliminate the positive discrepancy from long-run equilibrium. In addition, to check for the statistical adequacy of the VEC model, various diagnostic tests are conducted; and the test statistics, also presented in table 4, shows no clear evidence of serial correlation, heteroskedasticity, and non-normality.

6. Conclusions

Using data covering a twenty two year period and employing instrumental variable and vector error correction procedures, we analyzed the demand for domestic and imported paper and paperboard products in China. As expected, the empirical results indicate that income and price are important determinants of demand. For domestically made paper and paperboard products, the estimated income elasticity of the demand is about 1, indicating that the demand increases at the same speed of the economic growth. However, the demand does not respond to own-price in the early stage of economic reform; and it becomes about -0.7 as the reforms deepen. This result demonstrates that, because of the old centrally controlled planning system, the state-owned enterprises to a large extent were operated based on non-market oriented criteria with the result that demand is expected to be less sensitive to price. This changed with China's economic reforms. The demand response to international price also shows the same pattern: the demand is only responsive to price in the second stage of economic reform starting from 1993.

The demand for imports is also about unitary elastic with respect to economic growth. As expected, the demand for imported paper and paperboard respond negatively to increase of prices in the world market, yet the response in relatively inelastic, with an estimated own-price elasticity of -0.6. As economic transition progresses, the response appears to be even more inelastic. This is probably caused by the difference in quality between domestically made and imported products. As the reliance on some specific grade of high quality increases, the demand becomes less elastic. The relatively high income elasticity and low price elasticity of the demand for imports indicates that China has a huge market potential for international producers in this industry.

The demand for domestic product appears to respond to the price in world market with an estimated cross-price elasticity of 0.59. This is not surprising because imports can certainly be used as substitutes for domestically produced products. On the other hand, the demand for imports does not respond to domestic price. This indicates that domestically made products may not be used as substitutes for imports. This is certainly the case given the quality difference.

In order to address the issue of nonstationarity for variables in the demand function, we also estimated an error correction model to study the cointegration relationship and short run dynamics for the demand system for domestic products. The results from cointegration analysis are in line with the IV estimates. In addition, the error-correction term in the VEC model has a negative and statistically significant coefficient, which ensures a return to the long-run equilibrium if there is any deviation in the short-run.

Notwithstanding the small number of observations for this analysis, we are able to obtain interesting results, especially related to structural changes in demand. Among the implications of this analysis for future work is the need for a larger sample. With larger sample, we may be able to discern other structural changes and the effect of joining the WTO. A related limitation deriving from the sample size is an inability to test alternative econometric specifications based upon a richer set of explanatory variables.

PART II
FACTORS INFLUENCING THE U.S. LINERBOARD SUPPLY & DEMAND: A SIMULTANEOUS EQUATIONS MODEL

1. Introduction

Despite the excess capacity, involuntary inventory buildup, and high volatile price that continually characterize the U.S. linerboard industry, little research has been conducted on the industrial level to gain a better understanding of the forces driving the price of and demand for linerboard. This study reviews the U.S. linerboard industry, investigates linerboard demand and supply, and seeks to find the implication of variations in demand, costs, and price for the performance of linerboard industry. To this end, monthly data from January 1982 to December 1999 are utilized. One of the main purposes of this study is to obtain robust price and income elasticities of linerboard demand. We also examine the factors that influence price behavior, i.e., the response of price with respect to input costs and market-structure factors.

There have been numerous studies that focus on what variables determine the demand and price, yet few researches studying pulp and paper industry actually addressed the issue of simultaneity. Most of the previous researches examine the demand and price functions separately. On the demand side, for example, Buongiorno and Kang (1982) investigates short and long-run elasticities of U.S. demand for different paper and paperboard grades. Using monthly data from January 1967 to June 1979, they find that long-term price elasticities of demand for paper and for paperboard are -0.15 and -0.26, respectively. The corresponding income elasticities are 0.94 and 1.17. Chas-Amil and Buongiorno (2000) utilizes panel data from 1969 to 1995 to estimate paper and paperboard demand for 14 European Union countries. Their results indicate that paper and paperboard demands in European Union are price inelastic, and most of the changes in demand were attributed to GDP growth. Using annual data from 1971 to 2000, Hetemäki and Obersteiner (2002) provides projections for U.S. newsprint up to 2020. They find small even negative income elasticities, suggesting a structural change in newsprint consumption pattern after the end of the 1980s.

On the supply side, Dagenais (1976) presents a model of price determination for newsprint in eastern North America. The results indicate that costs and operating rate are the main determinants of newsprint prices. Chas-Amil and Buongiorno (1999) examines the determinants of prices of paper and paperboard in the European Union. In their study, prices of paper and paperboard are modeled as a function of input costs, scale of production, and technical change. With panel data over the period 1969-1992, they find a negative sign for technical change, indicating that technology advance decreases prices. They also find the presence of increasing returns to scale in the grade of other paper and paperboard, which, as they conclude, suggests monopolistic competition in this industry. But since the demand and supply are determined in a simultaneous system, estimation that ignores either demand or supply side will lead to biased and inconsistent results. In this study, the problem of simultaneity is addressed using simultaneous equations, along with the issue of over-identified, which occurs when a large numbers of exogenous variables are presented.

In light of recent mergers and acquisitions in the U.S. linerboard industry, concerns of market power and price manipulation arise. Most previous studies however didn’t take the possible oligopolistic nature into consideration. It is believed that a number of major segments of the paper and paperboard industry are oligopolistic markets, with a pattern of price leadership and with the big four or five companies usually accounting for at least 50% of total production. Rich (1978, 1983), for instance, describes the process of price determination in these segments (including linerboard) 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) allows for some degree of oligopoly in their models on U.S. forest products’ prices by adopting a mark-up pricing rule, in which the mark-up is assumed as a decreasing function of inventory-output ratio. They find that increases in inventory-output ratios always lead to decreases in prices for all seven segments studied, and the effects are statistically significant in four segments. The results support the hypothesis of mark-up pricing behavior. More recently, Booth et al. (1991) investigates the weak form of oligopolistic coordination in capacity expansion and pricing in the North American newsprint industry. The results indicate that operating rates have significant influence on price, which confirms the existence of barometric price leadership in the North American newsprint industry.

Yet, most industrial analysts believe that stiff competition remains in the U.S. linerboard industry, even though it is highly concentrated and only comprises of few homogeneous products. For instance, Steve Chercover (2003), an analyst with D.A. Davidson & Co. in Lake Oswego, argues that many paperboard products are selling into markets so full of competition that large producers such as Weyerhaeuser enjoy little leeway to raise prices. “The biggest producer is still going to be a price taker,” he said, “That is why it’s so important to control things that are in your control, which tend to be manufacturing costs."[19] John Lingle, president of Innovative Packaging Corp., also believes a competitive market structure for U.S. containerboard. He points out that the market for containerboard is so fragment that many people are fighting for market share and pricing is down to the marginal cost.[20]

Due to the on-going antitrust litigation against Smurfit-Stone Container Corporation (SSCC), one of the largest linerboard manufacturers, questions of whether or not market power exists, to what extent the market power is, and what is its impact are of particular importance to the U.S. linerboard industry. Allowing for some degree of oligopoly in the models is essential to gain insights in the U.S. linerboard and obtain robust price and income elasticity. In this study, besides developing a simultaneous equations model, we also incorporate market structure factors so that we can not only analyze the supply of and demand for U.S. linerboard but also investigate the market structure of the linerboard industry as well.

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; section VI concludes.

2. Linerboard Industry Characteristics

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 to study because of its global economic significance as

[19] Dylan Rivera (2003), "Nuts 'n' Bolts of Efficiency", available at www.oregonlive.com.
[20] Alby Gallun (1998), "Cardboard Companies seek price stability", Business Journal, available at http://milwaukee.bizjournals.com/milwaukee/stories/1998/12/07/story6.html.

well as recent merger activities and antitrust cases. First, it is one of the largest yet least differentiated segments of the paper industry. In 1999, for instance, 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 linerboard, accounting for 66.1% of the world's total production and consuming an estimated 57.9% of the global supply. Most of the linerboard produced in the U.S. goes into domestic corrugated container production process, with only 12.9% exported to customers overseas.[21] Yet 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, representing about 50% of total U.S. production. Other important grades are produced in weights of 26, 33, 38, 69 and 90 lb (lb/1000 sq. ft.).[22]

Several facts suggest potential market power in the linerboard industry. First, although the containerboard market is highly fragmented, certain large sellers such as SSCC and International Paper Co. have a disproportionate influence on domestic pricing. 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, the U.S. linerboard industry today 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,

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[21] The statistic source is *The International Fact & Price Book 2002*.
[22] The statistics resources 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.

International Paper, Georgia-Pacific Corp., Weyerhaeuser, and Inland Paperboard and Packaging Co. -- managed 66.5 percent of U.S. linerboard capacity.[23]

Furthermore, most linerboard producers are integrated with corrugated box firms. Integrated producer are those who make the materials need for boxes -- linerboard and corrugating medium, as well as the boxes. In terms of the corrugated box industry, about 80% of 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 tonnage is either supplied by integrated producers to their own box plants, or traded with other integrated producer to save on freight costs.[24]

Producers are now taking massive downtimes in order to fend off weak demand and maintain stable inventory levels. Such practices may be subject to antitrust charges, if there is a coordinated effort on the part 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

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[23] See *Pulp & Paper 2001 North American Factbook.*
[24] See *Pulp & Paper 2000 North American Factbook.*

such actions constitute an invitation to its competitors to join in a coordinated price increase.

But caution is needed when one asserts the U.S. linerboard industry as an oligopoly, because stiff competition remains or even intensifies during downtime. Price remains highly volatile in the past decade. In general, domestic linerboard prices tend to be highly 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 1970 to 1999 are noted with five major declines. The price drops happened during the years of 1981-1982, 1984-1985, 1989-1991 and 1992-1993, 1995-1997, in coincidence with the general economic recessions. Discounting usually spreads during recessions as producers fight for available orders to keep their capital-intensive mills running at high levels of capacity. Such tactics, however, normally backfire as other producers match the discounts, resulting in a general reduction. The existing problem of excess capacity exacerbates the price cut back in the industry. When the economy turns around, when operating rates lie in the 94% to 95% or higher range, when inventories are at about 6.2 to 6.3 weeks of supply or lower and in a downward trend, and when prices in export markets are strong, producers appear to have the most success in pushing through price increases.

3. Model Specification

3.1 Price Equation

To enrich our understanding of the linerboard industry as well as to obtain consistent estimates for both the supply and demand, we incorporate some degree of oligopoly in our research by assuming a pricing rule based on mark up over marginal cost (Yamawaki, 1984),

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

where P_t^* is the equilibrium price of linerboard in period t, λ_t is the mark-up factor, MC_t is the marginal cost function in period t, Q_t is the production of linerboard that clears the market, Z_t are exogenous variables on supply side, e.g. input prices, and ε_t is the supply error. When sellers are price takers, price equals marginal costs and λ_t equals one, however, when firms are not price takers firms set the target price higher than marginal costs and λ_t is larger than one. In this way, our model has the flexibility of accommodating different market structures.

If the U.S. linerboard market is highly competitive, as some analysts assert, the mark-up factor should be one with price equal to marginal cost. The marginal cost function can be derived by minimizing total cost, subjected to Cobb-Douglas production function. Assume that the production of linerboard is represented by a Cobb-Douglas function,

$$Q_t = \phi_0 L_t^{\phi_1} E_t^{\phi_2} M_t^{\phi_3} \quad (2)$$

where L_t, E_t, and M_t are labor, energy and materials (pulp) in time t, and r ($r = \Phi_1 + \Phi_2 + \Phi_3$) is the measurement of returns to scale, where $r < 1$, $r =1$ and $r >1$ imply decreasing, constant, and increasing return to scale respectively. Total cost of linerboard production is represented by

$$TC = W_t L_t + R_t K_t + P_t^m M_t + P_t^e E_t \quad (3)$$

Minimization of total cost under the assumption of Cobb-Douglas production function yields the minimum total cost,

$$TC^* = \theta_0 (Q_t)^{1/r} (W_t)^{\phi_1/r} (P_t^m)^{\phi_2/r} (P_t^e)^{\phi_3/r} \tag{4}$$

where $\theta_0 = r(\phi_0 \phi_1^{\phi_1} \phi_2^{\phi_2} \phi_3^{\phi_3})^{-1/r}$. The marginal cost function is computed as the change in total costs for a change in output produced:

$$MC(Q_t, Z_t) = \frac{\partial TC^*}{\partial Q_t} = \psi_0 (Q_t)^{\alpha_1} (W_t)^{\alpha_2} (P_t^m)^{\alpha_3} (P_t^e)^{\alpha_4} \tag{5}$$

where $\psi_0 = \theta_0/r$, $\alpha_1 = 1/r - 1$, $\alpha_2 = \Phi_1/r$, $\alpha_3 = \Phi_2/r$, and $\alpha_4 = \Phi_3/r$.

If the market has some degree of oligopoly, sellers can set the price higher than marginal cost by a multiplier of λ_t. The mark-up reflects the ease of coordination of the oligopoly as measured by the concentration ratio and operating rate in the industry. The concentration ratio reflects the degree of market power sellers may possess in price setting; therefore, we expect a positive sign for concentration ratio because price coordination is much simpler when the market is highly concentrated. The operating rate reflects industrial conditions which either facilitate or dampen intentional price coordinations. Rich (1983), for example, points out that the dividing line between strong demand and weak demand lies at an industry operating rate of about 93% over some sustained period of time. We expect operating rate has a positive association with the mark-up, because when the current state of demand is unexpected weak and leaves the firm with excess capacity, the firm expects to increase sales by lowering price. We postulated a mark-up function of

$$\lambda_t = \delta_0 e^{\alpha_1 OR_{t-1} + \alpha_2 CR_t} \tag{6}$$

where OR_{t-1} and CR_t are the operating rate and concentration ratio respectively.

By substituting equations (2) and (6) into (1) and taking the logarithm form, we obtain the price equation:

$$\ln P_t^* = \alpha_0 + \alpha_1 \ln Q_t + \alpha_2 \ln W_t + \alpha_3 \ln P_t^m + \alpha_4 \ln P_t^e + \alpha_5 \lambda_t + \varepsilon_t \quad (7)$$

To allow for time lag in the response of price to changes in profitability and capture the complete dynamics, lagged dependent variables are introduced into our final model.

3.2 Demand Equation

The demand for linerboard is a derived demand that arises from the demand for container box. In this study we assume that the demand equation follows

$$\ln Q_t^* = \beta_0 + \beta_1 \ln P_t + \beta_2 \ln P_t^s + \beta_3 \ln Y_t + u_t \quad (8)$$

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 as a proxy for the economic activities, and u_t is the disturbance term. Allowance is made for a lag in the response of demand to changes in the values of underlying determinants by positing an adjustment mechanism of the following form:

$$\frac{Q_t}{Q_{t-1}} = \left(\frac{Q_t^*}{Q_{t-1}}\right)^{\tau} \quad (9)$$

where Q_t is the quantity demanded in time t, Q_{t-1} is the demand for linerboard in previous period, and τ is the adjustment speed, $0 < \tau < 1$. Substituting (9) into (8), we obtain

$$\ln Q_t = \gamma_0 + \gamma_1 \ln P_t + \gamma_2 \ln P_t^s + \gamma_3 \ln Y_t + \gamma_4 \ln Q_{t-1} + u_t \quad (10)$$

Generally speaking, γ_1, γ_2, and γ_3 are interpreted as short-run own-price, cross-price and income elasticities of the demand for linerboard, respectively, and the ratios, $\gamma_1/(1- \gamma_4)$, $\gamma_2/(1- \gamma_4)$, and $\gamma_2/(1- \gamma_4)$ are the corresponding long-run demand elasticities.

4. The Data

Monthly data from January 1982 to December 1999 were collected for this study. The statistics sources for this analysis include American Forest & Paper Association (AFPA), U.S. Bureau of Labor Statistics, U.S. Federal Reserve, and Forest Products Laboratory (FPL) Data Set. The sale of linerboard transacted, proxy for the demand and supply in equilibrium, are measured as the output of the unbleached kraft linerboard minus the monthly change of inventory at linerboard mills. Due to the historical excessive inventory build-ups, we subtract the inventory change from quantity produced in order to control their effect. The monthly change of inventory is measured as the difference between the previous inventory and the current one. 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).

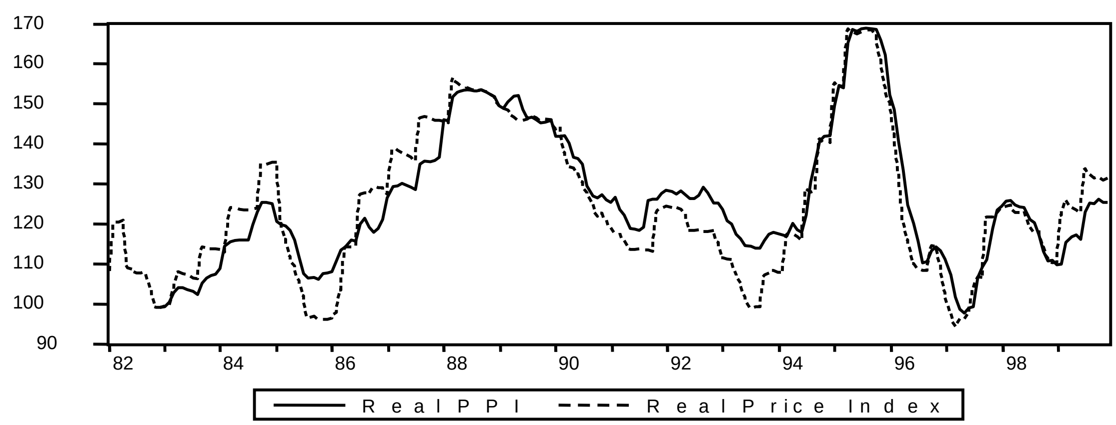

Figure 1. Real Price Index of 42lb Unbleached Linerboard and Real PPI for Linerboard

The linerboard price uses transacted price for 42lb unbleached linerboard taken from different issues of *Official Board Markets*. The price data set contains three different prices, a minimum, a maximum and an average price. We use the average price and normalize it with 1982 as base year. The resultant time series is the one shown in Figure 1, and will be used in the estimations. We compare the resultant price data with the U.S. Bureau Labor Statistics' producer price index (PPI) for unbleached linerboard over 1982-1999. As shown in Figure 1, the two time series share a similar pattern. The relationship between the linerboard sale and real price is shown in Figure 2. Substitute price is measured by PPI for polypropylene resins, a main material of plastic packaging, and is obtained from U.S. Bureau of Labor Statistics.

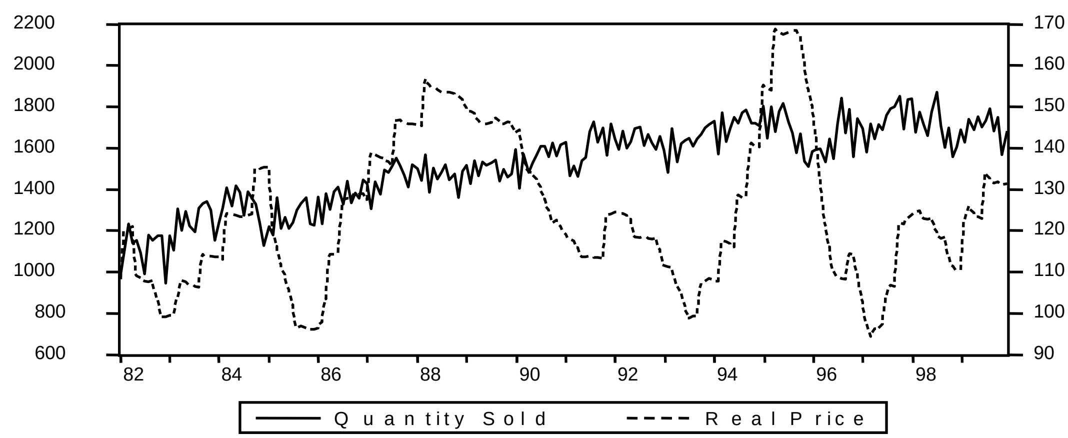

Figure 2. Real Price and Equilibrium Quantity of Linerboard, 1982-1999

We use PPI for pulpwood (including hardwood and softwood) and for electricity to measure the input prices of raw material and energy. The labor cost is measured as average weekly earnings of production workers at paperboard mills. Both the price indexes and earnings data are available from the U.S. Bureau of Labor Statistics. The total industrial production index, taken from the U.S. Federal Reserve Board, is used as a proxy of the economic activity. All nominal values, including price indexes and production index, are deflated with the producer price index for all industrial commodities with 1982 as base year. The operating rate is defined as the ratio of output to capacity, which was taken from '*AFPA Statistics for Time Series Analysis'*. Concentration ratio is calculated as the four-firm concentration ratio, which sums up the market shares of the four largest firms in the U.S. linerboard industry obtained from FPL data set. Only annual concentration ratio is available, thus we convert the annual concentration ratio to monthly time series and interpolate missing value by fitting a cubic spline curve to the input values. Figure 3 shows the historical relationship of real linerboard price index with operating rate. We also collected the data on the U.S. unemployment rate from the U.S. Bureau of Labor Statistics. None of the above variables are seasonal adjusted, and their summary statistics are shown in Table 5.

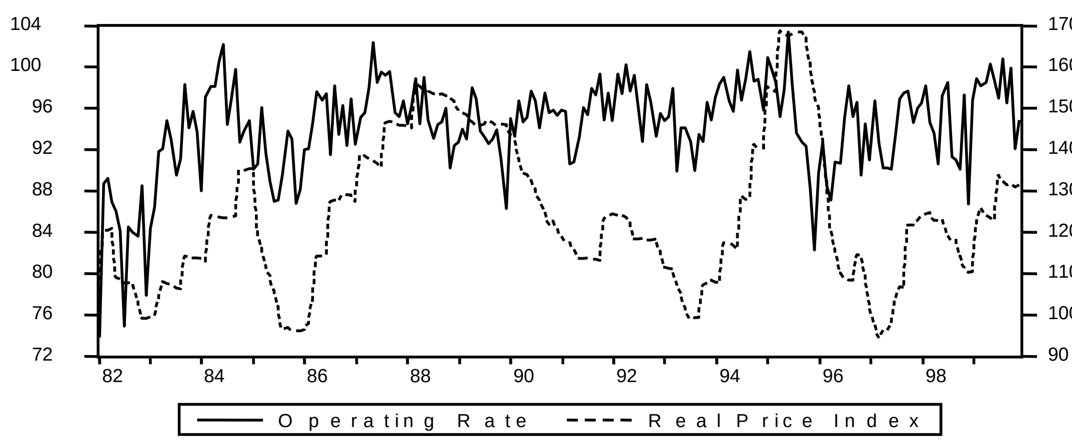

Figure 3. Operating Rate and Real Price of Linerboard, 1982-1999

Table 5. Descriptive Statistics

Variables	Description	Mean	STDV	Minimum Value	Maximum Value
Linerboard Sale	U.S. linerboard output excluding inventory, in thousand short tons	1518.43	198.15	946.4	1870.9
Linerboard Price	Real price indices of linerboard products in U.S.	124.39	18.09	94.41	168.79
Substitute Price	Real producer price indices of polypropylene resins	105.73	15.04	65.09	137.27
Production Index	Real U.S. total industrial production indices	117.34	11.53	94.46	147.03
Pulpwood Price	Real producer price indices of pulpwood	85.19	6.16	69.60	104.44
Energy Price	Real producer price indices of electricity for paper and paperboard industry	105.88	4.68	96.29	117.95
Wage Rate	Real wage rate of U.S. paper and paperboard industry	613.48	56.40	462.64	750.62
Concentration Ratio	The sum of top 4 companies' shares in total output	33.39	1.52	30.12	38.84
Operating Rate	Operating rate for unbleached Kraft paperboard in previous month	94.18	4.55	73.8	103.4
Unemployment rate	Total unemployment rate of the United States	6.42	1.58	3.7	11.4
CR*Unemployment	Interaction between concentration ratio and unemployment rate				

5. Empirical Results

Demand and supply functions based on equation (7) and (10) are jointly estimated by two stage least squares. The variables specified as endogenous are the sale of linerboard, 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 which increases the price of pulpwood. Therefore besides the predetermined variables on both demand and supply sides, the pulpwood price in the previous month is included as an instrumental variable for the pulpwood price. Table 6 reports the estimation results for a competitive linerboard market; Table 7 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 rate to capture seasonality in all other models. Results of the seasonal and yearly dummies are available upon request. The F-statistics for overidentification in our models are statistically insignificant, with only one exception (model 6), and suggest that the instrumental variables are valid in both demand and supply sides. No serial correlation exists, except model 1, indicating that a dynamic model specification is appropriate.

As indicated in Table 6 (Model 1), the response of demand to price is significant but inelastic, lying in the range of -0.08 to -0.14. The small magnitude of own-price elasticity is consistent with previous studies. Buongiorno and Kang (1982), for example, finds that the short-run price elasticities lie in the range from -0.10 for paper to -0.26 for paper and paperboard. Chas-Amil and Buongirono (2000) finds that the demand for paper

Table 6. Demand and Supply 2SLS Coefficients Estimates

Variables	**1**	**2**	**3**
Demand Functions/Linerboard Sale			
Constant	1.53** (0.83)	2.01* (1.05)	2.06** (1.01)
Linerboard Price	-0.13** (0.05)	-0.08* (0.05)	-0.14*** (0.05)
Production Index	0.23 (0.15)	0.25 (0.19)	0.17 (0.16)
Substitute Price	0.21*** (0.06)	0.16*** (0.05)	0.21*** (0.06)
Lagged Sales	0.14** (0.07)	0.33*** (0.07)	0.13* (0.07)
Lagged 12th Sales	0.45*** (0.06)	0.18*** (0.06)	0.44*** (0.06)
Unemployment rate			-0.006 (0.007)
Adjusted R^2	0.87	0.91	0.87
F-Statistics for overidentification	0.32 [0.81]	2.01 [0.11]	0.31 [0.82]
Supply Functions/Linerboard Price			
Constant	-2.4** (0.96)	-3.7** (1.57)	-1.86 (1.17)
Linerboard Sales	0.31** (0.10)	0.45** (0.13)	0.28** (0.11)
Pulpwood Price	0.21** (0.11)	0.26* (0.15)	0.26** (0.12)
Wage Rate	0.09 (0.09)	-0.06 (0.14)	0.03 (0.12)
Energy Price	-0.12 (0.09)	0.10 (0.21)	-0.12 (0.09)
Lagged price	0.84*** (0.03)	0.84*** (0.03)	0.83*** (0.03)
Unemployment rate			-0.005 (0.006)
Adjusted R^2	0.95	0.95	0.95
F-Statistics for overidentification	2.05 [0.11]	0.49 [0.68]	1.89 [0.13]

Note: *, **, *** = significant at 0.10, 0.05 and 0.01 level.

and paperboard is price inelastic in European Union, with price elasticities ranging from -0.13 to -0.30 for different countries. This result is possible because nearly 80% of corrugated box capacity in the U.S. is integrated with linerboard companies, which means companies have the ability to reduce the impact of price hike or crash and is less responsive to the changes of price.

Also shown in Table 6, the income elasticities for short-run are 0.17 to 0.25 and insignificant, suggesting that linerboard is a normal commodity and mainly determined by the shipments of manufacturing and durable goods. The small income elasticity is in line with previous studies. The substitute effect of plastic packaging is small but highly significant, with short run cross-price elasticity being 0.16 to 0.21 respectively, indicating that plastic packaging is a normal substitute for containerboard in certain segments of the packaging market such as groceries and auto parts. In other words, if the plastic price decreases by 10%, the demand for linerboard will decrease by 16~21% in the short-run.

On the price side, the coefficients of the input prices have plausible signs and magnitudes, but only that of pulpwood price is statistically significant. One explanation for the results is that raw material is a most important factor in the linerboard production process and thereby has a main influence on price. According to White (2002), pulp accounts for around 40 percent of the total cost, while labor and energy only account for 10 percent and 12 percent, respectively. Moreover Buongiorno and Lu (1989) also finds that a much larger part 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%.

Linerboard price exhibits a highly cyclical trend. The coefficient of output is very small but statistically significant, suggesting that a 10% increase in linerboard shipment leads to a 2.8~3.7% increase in price. This coefficient is larger than those in Chas-Amil and Buongiorno (1999). In their study, they find that coefficients before output range from -0.07 for other paper and paperboard to 0.02 for newsprint. The estimated coefficient before lagged price is 0.83 and highly significant, indicating a low rate of adjustment of 0.17. The low adjustment rate means the price rigidities are such that the linerboard price remains stable with occasional price revisions. The responses of the demand and supply to unemployment rate are of expected sign but insignificant.

As shown in Table 7, the above results are quite robust and remain almost unchanged after we incorporate different market-structure factors. With one exception, all operating rates and concentration ratios are of expected sign but insignificant, indicating that the U.S. linerboard industry has small or even no market power. Only operating rate in model 6 is significantly positive, however, this model didn’t pass the overidentification test for supply side. In general, the operating rate has a small coefficient ranging from 0.001 to 0.002, indicating a 1% increase in inventory in previous month will damp the price by 0.1~0.2%. The coefficients before concentration ratio are 0.003 and 0.004, indicating that a 1% increase in operating rate and concentration ratio will increase price by 0.3% and 0.4%, respectively. These insignificant results seem contradicted with the intensifying merger activities seen recently, but are possibly due to two factors. First, increasing concentration may have no impact on price but can largely decrease cost

Table 7. Demand and Supply 2SLS Coefficients Estimates

Variables	**4**	**5**	**6**	**7**	**8**
Demand Functions/Linerboard Sale					
Constant	2.02* (1.06)	2.02* (1.06)	2.04** (1.01)	2.05** (1.01)	2.05** (1.01)
Linerboard Price	-0.08* (0.05)	-0.07 (0.05)	-0.13** (0.05	-0.14** (0.05)	-0.14** (0.05)
Production Index	0.25 (0.19)	0.25 (0.19)	0.17 (0.16)	0.17 (0.16)	0.17 (0.16)
Substitute Price	0.16*** (0.05)	0.15*** (0.05)	0.20*** (0.06)	0.21*** (0.06)	0.21*** (0.06)
Lagged Sales	0.33*** (0.07)	0.33*** (0.07)	0.13* (0.07)	0.13* (0.07)	0.13* (0.07)
Lagged 12th Sales	0.18*** (0.06)	0.18*** (0.06)	0.44*** (0.06)	0.44*** (0.06)	0.44*** (0.06)
Unemployment rate			-0.006 (0.007)	-0.006 (0.007)	-0.006 (0.007)
Adjusted R^2	0.91	0.91	0.87	0.87	0.87
F-Statistics for overidentification	1.50 [0.20]	1.84 [0.12]	3.07** [0.02]	0.79 [0.54]	0.67 [0.65]
Supply Functions/Linerboard Price					
Constant	-2.62 (1.68)	-4.2** (1.66)	-1.63 (1.12)	-2.46* (1.25)	-2.88** (1.45)
Linerboard Sales	0.31* (0.16)	0.47*** (0.14)	0.21** (0.11)	0.31** (0.11)	0.31*** (0.11)
Pulpwood Price	0.34** (0.15)	0.29** (0.15)	0.31*** (0.12)	0.31** (0.13)	0.31** (0.13)
Wage Rate	-0.09 (0.14)	-0.04 (0.15)	0.01 (0.17)	0.04 (0.12)	0.04 (0.12)
Energy Price	0.04 (0.21)	0.09 (0.22)	-0.12 (0.09)	-0.13 (0.09)	-0.13 (0.09)
Lagged price	0.82*** (0.03)	0.84*** (0.04)	0.81*** (0.03)	0.83*** (0.03)	0.83*** (0.04)
Operating Rate	0.001 (0.001)		0.002** (0.001)		
Concentration Ratio		0.003 (0.005)		0.004 (0.004)	0.01 (0.04)
Unemployment rate			-0.005 (0.006)	-0.005 (0.006)	0.04 (0.08)
CR*Unemployment					-0.001 (0.002)
Adjusted R^2	0.96	0.95	0.96	0.95	0.95
F-Statistics for overidentification	0.42 [0.74]	0.46 [0.71]	0.67 [0.57]	1.87 [0.14]	2.02 [0.11]

Note: *, **, *** = significant at 0.10, 0.05 and 0.01 level.

which increases profit-margin. Second, our data set stops after 1999 and probably doesn't include the information of recent mergers and integrations. Interestingly, when the interaction term of concentration ratio and unemployment rate is included, we find that the coefficient before concentration ratio jumps to 0.01 which means a 1% increase in concentration ratio will increase the price by 1%. But as we expected, the interaction term is of negative sign, meaning the influence decreases as unemployment rate increases.

6. Conclusion

In this paper a simultaneous equations model is developed and monthly data from January 1982 to December 1999 are collected to investigate the demand for and supply of the U.S. linerboard industry. Our approach is unique in that we not only develop a simultaneous equations model but also explicitly incorporate mark-up factor into the model. More specifically, the mark-up factor is measured by operating rate and concentration ratio. The empirical results are quite robust across different model specifications. The price elasticity of linerboard demand, for example, lies in the range of -0.07 to -0.14. The income elasticity is in the range of 0.17 to 0.25 but insignificant, suggesting the demand is related with the performance of manufacturing and durable goods sectors. On the supply side, price is mainly influenced by linerboard shipments and material cost and shows strong rigidity. Unlike previous studies, mark-up factor does not have significant impact on price formation. All six models, except model 6 which shows operating rate has a positive and significant impact, suggest that mark-up factor is not an important determinant of price.

APPENDIX

Table A1. Augmented Dickey-Fuller Tests for individual variable

Variables	ADF-Statistics	LAGS	Trend	Intercept
Level				
Domestic Demand	-1.90	8	Yes	Yes
GDP	-3.61	6	Yes	Yes
Domestic Price	-2.06	1	No	Yes
First Difference				
Domestic Demand	-4.10**	3	No	Yes
GDP	-3.26**	6	No	Yes
Domestic Price	-4.01**	0	No	No

Note:
** = significant at 0.05 level.
The null hypothesis is the series has unit root.

Table A2. Johansen's cointegration test

Null Hypothesis	Alternative Hypothesis		5% Critical Value	1% Critical value
λ_{trace} test		λ_{trace} value		
R = 0	r > 0	93.49	47.21	54.46
R ≤ 1	r > 1	39.28	29.68	35.65
R ≤ 2	r > 2	14.21	15.41	20.04
λ_{max} test		λ_{max} value		
R = 0	r = 1	54.21	27.07	32.24
R = 1	r = 2	25.06	20.97	25.52
R = 2	r = 3	12.33	14.07	18.63

Note:
Test assumption: linear trends in the data but the cointegration equations have only intercept.
The 5 and 1 percent critical values for the trace statistics are calculated by Osterwald-Lenum (1992).
L.R. test indicates 1 cointegrating equation at 0.01 significance level in maximum eigenvalue tests.

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