Econometric Analysis of China's Plywood Market

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Abstract

China's primary wood-processing industry and wood-consuming sectors have experienced rapid growth in recent years. Plywood is the most important primary wood product in China in terms of consumption, production, and exports. One of China's most important export destinations is the United States, to which China exports not only plywood but also wood in the form of furniture. In this article, we analyze the development of China's plywood industry since the 1990s; provide an overview of the demand, supply, and exports of Chinese plywood; and present the results of econometric models. The Engle–Granger error-correction model was applied to an analysis of annual time-series data from 1993 to 2007. The results suggest that most of the growth in China's plywood demand was primarily driven by the growth in consumer income, while an increase in product price had only a small negative effect. In contrast, an increase in raw material price had a significant negative impact, but end-use sector activity had no significant effect on China's plywood supply. During the same period, the growth in China's plywood exports was due to consumer income growth in the US market. Knowledge of the elasticities and findings presented here can serve as a useful reference for foreign and domestic wood product companies that plan their investments, as well as government agencies and public authorities that plan economic and forest policies.

China's unprecedented economic growth over the past three decades has resulted in a strong demand for a wide variety of commodities. As part of this, the growth in global demand for forest industry products is shifting from Europe and North America to China. China's booming economy, huge population, growing construction activities, and housing reforms have driven a dramatic increase in its consumption of wood and wood products for infrastructure development, building construction, interior decoration, and furniture manufacturing. Market growth is also a major driver in attracting foreign direct investments (FDIs) in the forest industry to China (Ernst & Young 2009). With China's incentive policies on forestry development and a growing demand for low-cost wood industry products in developed countries, many companies have invested in China's wood-processing industry in recent years. China has become the world's wood workshop, exporting price-competitive value-added wood products, primarily furniture, followed by plywood (Wan 2009).

China is the world's largest furniture exporter, with the United States as its largest export destination. In 2007, China exported 43.5 percent of its furniture to the United States and 22.1 percent to the European Union. China was also the world's largest plywood exporter, and the United States was China's second largest destination country. Followed by Saudi Arabia, the United States imported 9.6 percent of its plywood from China in 2007 (Alberta China Office [ACO] 2008). Nevertheless, because of increasing labor and production costs, the dependence on log imports, the appreciation of the Chinese renminbi, and the reduced export tax refund in China, as well as the recent anti-dumping and more stringent environmental regulations in the United States and the downturn in the US housing market, the competitive advantage of Chinese manufacturers has been weakened. This has forced the United States to seek lower-cost locations, such as Vietnam or Cambodia (Buehlmann and Schuler 2009), and encouraged some large Chinese export-oriented wood products companies to switch their focus back to the domestic market and to expand the market share in other areas, such as the Middle East, Africa, and Japan (ACO 2008). At the same time, the increasing sensibility of consumers for more environmentally friendly products will offer advantages for US domestic furniture manufacturers who intend to produce mass-customized and

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green furniture (Buehlmann and Schuler 2009). Even though the impact of the recent global economic recession has negatively affected China's wood products trade, in late 2008 the Chinese government took swift actions to stimulate domestic demand by implementing policies of reducing taxes and local interest rates for residential purchases by 30 percent (Wood Markets Report 2010).

However, few studies have addressed China's forest products markets. For example, Li et al. (2006) examined the pattern of demand for paper and paperboard products in China. Wang and Wu (2000) investigated the influential factors affecting markets in Taiwan, as related to the demand for and supply of plywood. Yet, due to the limited availability of reliable time-series data so far, academic research on China's wood products markets is scarce. Since plywood is an important export product of China's wood products industry in international markets and an important raw material for China's huge furniture industry, we focus here on China's plywood market. We analyze the market situation by estimating econometric models of the factors affecting the demand, supply, and exports of Chinese plywood. Because China's plywood industry has experienced rapid growth since the early 1990s, we undertake analysis of the period from 1993 onward.

In the following section, we review the development of China's plywood industry. We then outline the econometric models used in the statistical analysis, describe the methods and data used, and present the empirical results. We finally briefly discuss the findings, compare the results with those from previous studies, and identify the main areas for future research.

Development of China's Plywood Industry

China's soaring economic growth has caused a surge in the construction of housing, luxury hotels, and office spaces. Improved living standards and the emergence of a wealthy class of consumers have translated into an increased demand for high-quality wood for home and office decoration and furnishing (Sun et al. 2005). China's housing reform, which aims to achieve the privatization of public housing, has stimulated the demand for affordable, energy-efficient, and high-quality homes with better amenities, and has thus propelled the need for decorative wood products. Because of a huge population and the progress of urbanization, the Chinese government has been undertaking initiatives to increase housing supply. In response to booming domestic demand for these robust residential construction-related activities and real estate development, China's plywood industry, especially hardwood plywood industry, has grown dramatically. Hardwood plywood is used as the preferred material for interiors, floor molding, wall panels, doors, windows, and kitchen cabinets, while softwood plywood is used extensively in housing construction.

Market growth is also a major driver in attracting FDIs in the forest industry in China (Ernst & Young 2009). With the arrival of numerous foreign enterprises and the creation of joint ventures, especially with China's entrance into the World Trade Organization, inflows of FDIs have increased spectacularly. The high costs of local labor, land, and raw materials, as well as limited domestic markets have encouraged plywood enterprises in Taiwan, Hong Kong, Singapore, and other countries to invest in and move their facilities to China. The introduction of modern equipment, tight quality control, and constant improvements in technology have helped ensure that Chinese plywood meets international market quality standards (Adams and Ma 2002). The statistics of the State Forestry Administration of China show that the production of Chinese plywood increased from 2.13 million m^3 in 1993 to 35.62 million m^3 in 2007. Hardwood plywood accounted for approximately 85 percent of China's total plywood production. About 80 percent of hardwood plywood production was used for furniture, nonstructural building material, and the interior decoration industry (United States International Trade Commission [USITC] 2008). In 2003, China already surpassed the United States and became the world's largest plywood producer. China's rapidly increasing plywood production will necessitate greater future log imports. As an example, Ashley, one of the largest US furniture companies, has established a factory in Kunshan County, Jiangsu Province, China. The furniture made there is tapping into not only China's retail markets, but also the American and global markets (ACO 2008).

China's plywood industry is highly fragmented, consisting of a large number of small-sized companies and a small number of medium- and large-sized entities. It has been estimated that there are over 5,000 plywood mills: small-sized mills play a vital role in China's plywood industry, while medium-sized and large mills, respectively, account for 30 percent and less than 10 percent of the total plywood capacity in China. There are four plywood-manufacturing bases in China: Pizhou in Jiangsu Province, Jiashan in Zhejiang Province, Linyi in Shandong Province, and Zhengding in Hebei Province. Pizhou plays a key role in China's growth as the world's largest exporter of plywood because over 35 percent of plywood manufacturers in this area export their production. In Jiashan, the plywood sector has become this county's pillar industry. However, exports can be difficult for the mills there because of the remoteness of the plantations (Rutten and Tan 2004).

China began to import plywood in the 1980s. From 1993 to 2007, China's plywood trade developed at a frantic pace. Figure 1 shows that 1998 was a watershed year for China's imports of logs and plywood. Prior to 1998, China's imports of tropical timber were dominated by the low-cost plywood from Indonesia and Malaysia. It severely undermined the competitive position of Chinese manufacturers, so the Chinese authorities had to remove log import tariffs and

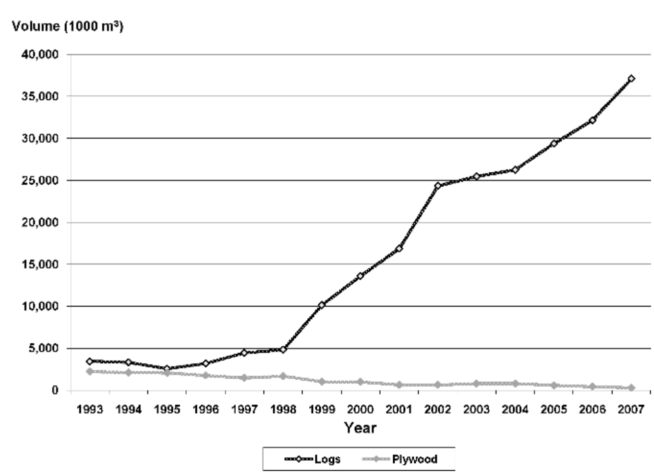

Figure 1.—China's imports of logs and plywood from 1993 to 2007 (for various statistical sources, see Wan 2009).

crack down on plywood smuggling. Triggered by China's logging ban and reduction of log import tariffs to zero, a slow decline in log imports suddenly became a rapid escalation after 1998.

Figure 2 demonstrates the reverse trends in the trade of China's plywood: plywood imports plunged from 2.23 million m^3 in 1993 to only 306,600 m^3 in 2007. Imported plywood in 2007 mainly came from Indonesia and Malaysia, representing 45.8 and 32.7 percent, respectively (Wan 2009). Because of the price competitiveness of plywood production as a labor-intensive industry in international markets, China's plywood exports underwent dynamic growth, soaring from 94,000 m^3 in 1993 to 8.78 million m^3 in 2007. In contrast, the import volume has been insignificant and has declined in recent years. In 2001, China's plywood exports exceeded its imports for the first time, and since then China has become a net plywood exporter, mainly targeting the US, Japanese, and UK markets (Wan 2009). Since 2003, China has become the world's largest exporter of plywood (Ma 2008). From 2002 to 2006, China's hardwood plywood exports to the United States increased eightfold, largely driven by growth in the US housing market (USITC 2008). China's apparent consumption of plywood, calculated as production plus imports minus exports, increased from 4.26 million m^3 in 1993 to 27.14 million m^3 in 2007 (Wan 2009). As shown in Figure 2, two-thirds of the production was to meet domestic demand. Hardwood plywood sold into the Chinese domestic market reportedly tended to be used to make furniture, which was often exported to the developed country markets, including the United States (USITC 2008).

Theoretical Background

Analysis of China's plywood market is based on the model structures presented in previous research on forest products market modeling. In a pioneering study, Buongiorno (1979) modeled the demand for forest industry products as consumer demand, and thereafter modeling demand has commonly been based on the derived demand approach (Buongiorno 1996, Buongiorno et al. 2003, Hetemäki et al. 2004, Hänninen et al. 2007). To model the imports and exports of forest products, the Armington (1969) theory is often applied (Hänninen 1998a, 1998b; Hänninen and Toppinen 1999). Product supply in simple form can be presented as a function of its price (Koutsoyiannis 1977) and end-use sector activity (Buongiorno et al. 2003).

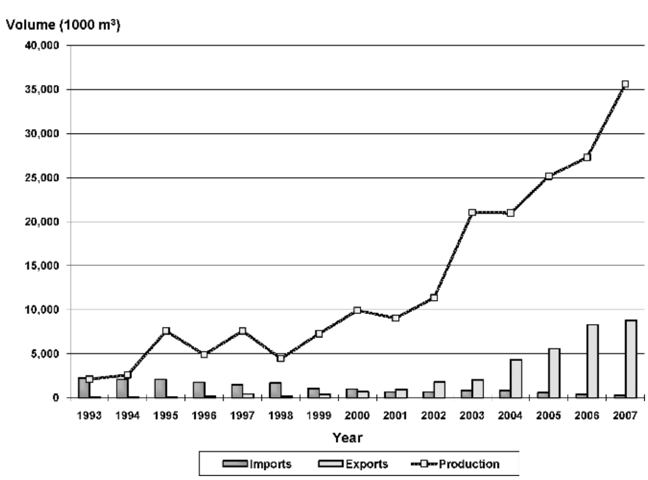

Figure 2.—China's production and trade of plywood from 1993 to 2007 (for various statistical sources, see Wan 2009).

Plywood demand model

China's apparent consumption of plywood was formulated, using the classic double-logarithmic formula (Buongiorno 1979), in which consumption was explained by consumer income and the real domestic price of plywood in China. Because there were no exact data available at the annual level over the study period, data existing for China's real gross domestic product (GDP) and the real unit export price of Chinese plywood were used as proxies. Therefore, the estimable equation, after the logarithmic transformation of variables, can be expressed as follows:

$$\mathrm{LACP}_t = a + \underset{+}{b}\mathrm{LGDPR}_t + \underset{-}{c}\mathrm{LEPR}_t + u_t \qquad (1)$$

where LACP is China's apparent consumption of plywood, LGDPR is China's real GDP, LEPR is the real export price of Chinese plywood, a is a constant, b and c are, respectively, the income elasticity and price elasticity of demand, u is an error term, and t represents time. The symbols under the coefficients denote the expected signs of the estimated coefficients: + represents the positive sign and – represents the negative sign.

Plywood supply model

China's supply of plywood was presented as a function of price (including both product price and raw material price) and end-use sector activity. The supply of plywood and end-use sector activity were described by the production volume of plywood and wooden furniture, respectively, while the product price and the price of raw material for plywood production were separately represented by the real plywood price and the real log price. Since there were no exact data available over the study period, data existing for the real unit export price of Chinese plywood and the real unit import price of Chinese logs were used as proxies for the real domestic prices of Chinese plywood and logs, respectively. Consequently, the estimable equation of plywood supply can be presented in the following logarithmic form:

$$\mathrm{LQP}_t = a + \underset{+}{b}\mathrm{LWFQ}_t + \underset{+}{c}\mathrm{LEPR}_t + \underset{-}{d}\mathrm{LIPR}_t + u_t \qquad (2)$$

where LQP is the production volume of Chinese plywood, LWFQ is the production volume of Chinese wooden furniture, LEPR is the real export price of Chinese plywood, LIPR is the real import price of Chinese logs, a is a constant, b is supply elasticity with respect to the production of Chinese furniture, c and d are, respectively, the plywood price elasticity and the log price elasticity of supply, u is an error term, and t represents time. As in Equation 1, the symbols under the coefficients denote the type of expected signs (positive and negative) of the estimated coefficients.

Plywood export model

China's exports of plywood were modeled, using the Armington (1969) export demand theory. As the largest export destination of Chinese plywood products, the United States here represented the whole of China's export markets.

Following Armington's theory, China's exports of plywood were explained by consumer income in the export markets and the real export price of Chinese plywood. Proxies for describing the empirical variables were also needed in this model: the income variable of the export markets was described by the US real GDP, and the real unit export price of Chinese plywood to the United States was described by the unit price of Chinese total plywood exports deflated by the US market deflator (Wan 2009). The logarithmic form of the specification is

$$\text{LEP}_t = a + b\underset{+}{\text{LUS}_t} + c\underset{-}{\text{LEPR}_t} + u_t \tag{3}$$

where LEP is the total export volume of Chinese plywood, LUS is the US real GDP, LEPR is the real export price of Chinese plywood, a is a constant, b and c are, respectively, the income elasticity and price elasticity of export demand, u is an error term, and t represents time. As in Equations 1 and 2, the symbols under the coefficients denote the expected signs (positive and negative) of the estimated coefficients.

Methods and Data

We applied the Engle–Granger (Engle and Granger 1987) error-correction method (ECM) to make econometric estimations in two steps, which was separating the long-run from short-run effects in modeling the plywood market. In general, sound time-series modeling should describe both long-run equilibrium and short-run dynamics simultaneously (Asteriou and Hall 2007). For this purpose, the residuals from the long-run equilibrium regressions were used after the first-step estimation to estimate the ECM. This in turn was used to analyze the long-run and short-run effects of the variables and to view the adjustment coefficient. This coefficient is called the lagged error-correction term (ECT) and it is the lagged residual terms of the long-run relationship (Asteriou and Hall 2007). The ECM combines the information from the long-run relationship found in the cointegration analysis with the short-run dynamic factors (Engle and Granger 1987).

However, before modeling, we needed to utilize the augmented Dickey–Fuller (ADF) unit root test method (Dickey and Fuller 1979, Abildtrup et al. 1999, Helles et al. 1999) to test for stationarity of a time series. Then, according to the Engle–Granger (1987) procedure, we used the ordinary least squares (OLS) regression method to estimate Equations 1, 2, and 3 and obtain their residuals. With the help of the ADF test, we were also able to test for stationarity of the residuals. If the residuals are stationary, the variables are cointegrated and have a long-run equilibrium relationship (Asteriou and Hall 2007). For the residual diagnostic tests in both stages, the Breusch–Godfrey (BG), Lagrange Multiplier (LM), and Jarque–Bera (JB) tests were performed individually for autocorrelation, heteroskedasticity, and normality in the residuals.

The empirical analysis was performed, using EViews statistical software (Quantitative Micro Software, LLC, Irvine, California). The elasticities of demand, supply, and exports of Chinese plywood were estimated by employing annual data over the period of 1993 to 2007. We suggested that this 15-year sample represented the most meaningful data span in modeling China's plywood market. Despite a small number of observations, we noted that an increase in either the data span or the data frequency to the monthly or quarterly level would not enable us to extract essential information on the adjustment of these markets. However, the small number of observations did not allow us to use system estimation, thus results of Equations 1 to 3 must be estimated separately.

The detailed data sources were explained in Wan (2009), with the most important sources being China Statistical Yearbook, China Customs Statistics, the State Forestry Administration of China, the National Bureau of Statistics of China, the World Bank Development Indicator Database, and the US Bureau of Labor Statistics. China's GDP, the export price of Chinese plywood, and the import price of Chinese logs were originally in nominal US dollars, but they were converted to real dollars by the GDP deflator for China, with 2004 as the base year. The US real GDP was converted to US dollars, using 2005 purchasing power parities (Wan 2009).

Results

Before forming and estimating the models, it is essential to analyze the time-series properties of the data, for example, normality and stationarity. The JB test showed that all series appeared to be normally distributed. The results of the ADF unit root tests, presented in Table 1, indicated that there were stationary and nonstationary variables of order 1 in the data set. The LEP, LQP, and LWFQ were stationary in levels, while the LACP, LEPR, and LIPR were nonstationary in levels but became stationary in first differences. The LUS was nonstationary in both levels and first differences but became stationary in second differences. In contrast, the test result for the LGDPR was unclear because it was nonstationary not only in levels but also after the second differencing.

Next, the models were estimated in two stages. In the first stage, we applied the OLS to estimate the demand, supply, and export functions for Chinese plywood, in which logarithmic variables were utilized. In the second stage, we estimated the short-run ECM models. These results are shown in Tables 2 and 3, respectively.

Plywood demand model

The first-stage estimation results for the Chinese plywood demand model shown in Table 2 are expressed by Equation 4 with t values in parentheses:

$$\text{LACP}_t = \underset{(1.14)}{3.13} + \underset{(6.77)}{1.11 \cdot \text{LGDPR}_t} - \underset{(-1.00)}{0.33 \cdot \text{LEPR}_t} + u_t \tag{4}$$

where all the estimated coefficients showed the expected signs and China's plywood demand (LACP) appeared to be income elastic but price inelastic, while the price effect on LACP was not statistically significant. As indicated in Table 2, the adjusted R^2 explained 85 percent of the variance in the LACP series and the F statistic showed that the coefficients were generally significant. Nonetheless, it should be borne in mind that in the presence of nonstationary variables, the t statistics did not follow a standard t distribution; hence these long-run coefficients cannot be interpreted as usual. The BG, JB, and LM tests indicated no problem with autocorrelation, normality, and heteroskedasticity in the residual series. Based on the ADF statistic, the residuals were stationary, and thus we assumed that the variables in the long-run demand model were cointegrated. Therefore, we proceeded to the second-stage estimation.

Table 1.—ADF unit root tests for the variables in levels and differences from 1993 to 2007.

Variable[a]	Lag, determination	t-ADF	Significance level[b]	Decision[c]
Levels				
LACP	L = 3, Trend and intercept	−3.49	*	$I(1)$
LEP	L = 3, Trend and intercept	−3.85	**	$I(0)$
LEPR	L = 3, Trend and intercept	−0.34		$I(1)$
LGDPR	L = 3, Trend and intercept	−0.49		$I(1)$
LIPR	L = 3, Trend and intercept	−0.45		$I(1)$
LQP	L = 3, Trend and intercept	−3.93	**	$I(0)$
LUS	L = 3, Trend and intercept	−1.95		$I(1)$
LWFQ	L = 3, Trend and intercept	−3.90	**	$I(0)$
First differences				
ΔLACP	L = 3, None	−4.80	***	$I(0)$
ΔLEPR	L = 3, None	−3.51	***	$I(0)$
ΔLGDPR	L = 3, None	0.95		$I(1)$
ΔLIPR	L = 3, None	−3.02	***	$I(0)$
ΔLUS	L = 3, None	−1.23		$I(1)$
Second differences				
Δ^2LGDPR	L = 3, None	−1.82	*	$I(1)$
Δ^2LUS	L = 3, None	−3.55	***	$I(0)$

[a] Δ = the first difference of the variable; Δ^2 = the second difference of the variable.
[b] *, **, *** = coefficients are significantly different from zero at the 10, 5, and 1 percent confidence levels, respectively.
[c] $I(0)$ = stationary series; $I(1)$ = nonstationary series.

Table 2.—Long-run equations from 1993 to 2007.[a]

Variable	Chinese plywood demand model	Chinese plywood supply model	Chinese plywood export model
Constant	3.13 (1.14)	11.23 (3.18)***	−175.91 (−11.60)***
China's GDP	1.11 (6.77)***		
Export price of Chinese plywood	−0.33 (−1.00)		
Production volume of Chinese wooden furniture		0.72 (3.90)***	
Import price of Chinese logs		−1.67 (−3.35)***	
US GDP			17.13 (12.04)***
Adjusted R^2	0.85	0.79	0.91
Durbin–Watson statistic	2.04	2.25	0.97
Prob (F statistic)	0.00	0.00	0.00
F statistic			
BG test	0.10	1.41	1.41
JB test	0.54	1.10	3.04
LM test	0.45	0.54	1.98
ADF test statistic	−3.68***	−4.14***	−2.27**
Test critical values			
1% level	−2.74	−2.74	−2.74
5% level	−1.97	−1.97	−1.97
10% level	−1.60	−1.60	−1.60

[a] Numbers in parentheses are t values. R^2 = coefficient of determination; Prob = probability. *, **, *** = coefficients are significantly different from zero at the 10, 5, and 1 percent confidence levels, respectively.

In the second stage, the ECM was estimated, using the first differences of the variables, and the error term was obtained from the first-stage model. $\mathrm{ECT}_{(t-1)}$ is the lagged error correction term. The results presented in Table 3 are expressed by Equation 5 with t values in parentheses:

$$\Delta\mathrm{LACP}_t = \underset{(-1.02)}{-0.20} + \underset{(1.80)}{2.93 \cdot \Delta\mathrm{LGDPR}_t} - \underset{(-0.75)}{0.52 \cdot \Delta\mathrm{LEPR}_t} - \underset{(-2.73)}{0.99 \cdot \mathrm{ECT}_{(t-1)}} \quad (5)$$

where the income and price coefficients also showed the expected signs in the short run. The coefficient of the lagged ECT measures the speed of adjustment of the response variable toward its long-run value. It indicated that the LACP almost fully adjusted (over 99%) in 1 year. In contrast, the adjusted R^2 (0.53) in first-difference form was lower than in level form, but otherwise the residual terms functioned according to the diagnostic tests.

Plywood supply model

The estimated first-stage coefficients of the plywood supply model shown in Table 2 are expressed by Equation 6.

Table 3.—Dynamic equations estimated by ECM from 1993 to 2007.[a]

Variable	Chinese plywood demand model	Chinese plywood supply model	Chinese plywood export model
Constant	−0.20 (−1.02)	0.15 (1.92)*	0.22 (0.88)
China's GDP	2.93 (1.80)*		
Export price of Chinese plywood	−0.52 (−0.75)		
Production volume of Chinese wooden furniture		0.40 (1.92)*	
Import price of Chinese logs		0.94 (1.51)	
US GDP			4.82 (0.43)
Coefficient for ECT	−0.99 (−2.73)**	−0.92 (−4.50)***	−0.50 (−2.08)*
Adjusted R^2	0.53	0.63	0.15
Durbin–Watson statistic	1.87	2.04	2.52
Prob (F statistic)	0.01	0.00	0.16
F statistic			
BG test	0.21	0.46	1.28
JB test	1.02	0.22	10.06
LM test	0.80	1.07	0.05
ADF test statistic	−3.25***	−3.60***	−4.51***
Test critical values			
1% level	−2.75	−2.75	−2.75
5% level	−1.97	−1.97	−1.97
10% level	−1.60	−1.60	−1.60

[a] Numbers in parentheses are t values. R^2 = coefficient of determination; Prob = probability. *, **, *** = coefficients are significantly different from zero at the 10, 5, and 1 percent confidence levels, respectively.

The plywood price, LEPR, was dropped from Equation 4 because the estimated coefficient showed a wrong and negative sign. Therefore, the resulting regression equation with t values in parentheses is

$$\mathrm{LQP}_t = \underset{(3.18)}{11.23} + \underset{(3.90)}{0.72} \cdot \mathrm{LWFQ}_t - \underset{(-3.35)}{1.67} \cdot \mathrm{LIPR}_t + u_t \quad (6)$$

where the coefficients for both the production of Chinese wooden furniture (LWFQ) and the real price of logs (LIPR) had the expected signs, implying that an increase in the LWFQ increased the domestic supply of plywood, while an increase in the LIPR decreased the domestic supply of plywood. China's supply of plywood (LQP) appeared to be dependent on LWFQ and LIPR. Apparently, the unit export price of plywood was not a suitable proxy variable for the domestic plywood price. As a result, the effect of plywood price on its supply was not possible to estimate. The long-run supply model (Eq. 6) showed a good fit because the adjusted R^2 explained 79 percent of the variance in the LQP series. The coefficients were significant according to the F statistic. Nevertheless, the t statistics again did not follow the standard t distributions due to the presence of nonstationary time series. The residual tests indicated that this model likewise did not suffer from autocorrelation, normality, or heteroskedasticity, and the residuals were stationary according to the ADF statistic. Thus, the variables in the long-run supply model were also assumed to be cointegrated.

The ECM was estimated based on the first-stage regression equation. The results presented in Table 3 are expressed by Equation 7 with t values in parentheses:

$$\Delta\mathrm{LQP}_t = \underset{(1.92)}{0.15} + \underset{(1.92)}{0.40} \cdot \Delta\mathrm{LWFQ}_t + \underset{(1.51)}{0.94} \cdot \Delta\mathrm{LIPR}_t - \underset{(-4.50)}{0.92} \cdot \mathrm{ECT}_{(t-1)} \quad (7)$$

The short-run results demonstrated that the coefficient of the first difference of LWFQ, denoted by ΔLWFQ, showed the expected sign, but the coefficient of the first difference of LIPR, denoted by ΔLIPR, was positive, which ran counter to what we would expect from economic theory. However, the effect in the short run may differ from that in the long-run relation because economic theory concerns long-run equilibrium. The coefficient of the lagged ECT indicated that the LQP adjusted by over 92 percent in 1 year. Compared with the long-run model, the adjusted R^2 in the ECM (0.63) was reasonably low and the tests indicated no serious problems with autocorrelation, normality, or heteroskedasticity in the residual series.

Plywood export model

The first-stage estimation results for the Chinese plywood export model shown in Table 2 are expressed by Equation 8. In this model, the estimated coefficient of the export price of Chinese plywood, LEPR, also showed a wrong sign, so it was dropped from Equation 3. Thus, the resulting regression equation with t values in parentheses is

$$\mathrm{LEP}_t = \underset{(-11.60)}{-175.91} + \underset{(12.04)}{17.13} \cdot \mathrm{LUS}_t + u_t \quad (8)$$

The coefficient of the US real GDP (LUS) showed the expected sign and China's exports of plywood (LEP) were highly dependent on US consumer income. According to the economic theory, the export demand depends negatively on the export price of the product, but in the estimation the coefficient was positive. Possible reasons for this might be the inaccuracy of the unit price of Chinese total plywood exports representing the Chinese plywood export price to the United States or multicollinearity between the GDP and price in the model. With 0.91 for the adjusted R^2, the long-run model again showed a good fit. The residual tests indicated no problems with autocorrelation, normality, or heteroskedasticity, and the residuals were stationary based on the ADF statistic. Likewise, we assumed that the variables in the long-run export model were cointegrated.

In the second stage, the results of the ECM estimation for plywood exports presented in Table 3 are expressed by Equation 9 with t values in parentheses:

$$\Delta \mathrm{LEP}_t = \underset{(0.88)}{0.22} + \underset{(0.43)}{4.82} \cdot \Delta \mathrm{LUS}_t - \underset{(-2.08)}{0.50} \cdot \mathrm{ECT}_{(t-1)} \quad (9)$$

The short-run income elasticity showed the expected positive sign, but it was not statistically significant. The coefficient of the lagged ECT indicated that the LEP adjusted by over 50 percent in 1 year, meaning that it required about 2 years for the total market adjustment. However, the F statistic showed that not all of the regression coefficients were significant, and consequently we concluded that the results of the export model were not satisfactory, probably due to problems in the first-stage estimation.

Discussion and Conclusions

By using statistical analysis of China's plywood market and an econometric error-correction modeling approach, this article estimated, for the first time, the long-run and short-run elasticities of demand, supply, and exports of plywood in China. As expected from economic theory, our empirical results demonstrated that both income and product price were important demand determinants, but the income effect was the dominating driver. With the roughly unitary income elasticity of demand (1.11), China's demand for plywood increased at almost the same speed as China's economic and consumer income growth. The similar magnitude of the long-run income impact was found in a previous study by Li et al. (2006) of China's paper market, while in Buongiorno (1979) the estimated long-run income elasticity of demand for plywood, based on international data, was 0.95. Compared with the long-run impact, the short-run income effect on China's plywood demand was considerably lower. With respect to the price of Chinese plywood, it affected China's plywood demand in the long run but not in the short run. The magnitude of long-run low price elasticity of China's demand for plywood (–0.33) also reflected the fact that if a commodity was used in small quantities in the consumer economy, its price might not play such an important role in its markets. This is exactly the case in the use of plywood in Chinese construction, wooden furniture, or other relevant end uses. Although there is an increasing domestic demand for plywood in China, the use of plywood is in relatively small quantities in the construction and furniture sectors given its large land area and huge population. The low price elasticity might also be due to the use of proxy price (export price) instead of the exact price variable (domestic price), as well as the fact that the Engle and Granger (1987) method cannot be used for two-stage least squares estimation of price endogeneity.

Our estimations showed the domestic supply elasticity of Chinese plywood in relation to the raw material price (Chinese import unit price of logs) and end-use sector activity (production of domestic wooden furniture) were −1.67 and 0.72, respectively. This revealed that China's supply of plywood was highly elastic with regard to log price changes but inelastic with respect to the production of wooden furniture, meaning that changes in log markets, but not the production of furniture, had a significant negative effect on the plywood supply in China. Our results can be compared with those of Wang and Wu (2000), who estimated the domestic supply elasticity of plywood in Taiwan with respect to the raw material price (import price of hardwood logs) and end-use sector activity (area of domestic house building) as −1.02 and 0.31, implying that the supply of plywood in Taiwan decreased at almost the same rate as the increase in log price but was even more inelastic with regard to end-use sector activity. Because of China's limited forest resources and the rising price of imported logs from Russia, the domestic log supply has failed to match the growing demand for logs. In fact, raw material supply is currently the biggest challenge faced by China's plywood industry. In an effort to retain its competitiveness in the global wood products markets, China will clearly have to find new sources for logs and the Russian Federation would be the most likely source if the export tariffs were not raised too high (Solberg et al. 2010). From the foreign investors' point of view, there may be some alternative solutions; for example, they may jointly develop the plantations in China with local Chinese partners or import logs with reasonable delivery prices to China. Most notably, US hardwood log exports to China increased by 328 percent between 2002 and 2007 (Schuler and Buehlmann 2008). Corresponding to the above results, the insignificant effect of furniture production on China's supply of plywood again implied that the use of plywood is still in small quantities in the furniture sector in China.

Based on the econometric results, China's exports of plywood were highly dependent on US consumer income. Apart from this, there are some other factors that could impact Chinese plywood exports to the United States in the future but were difficult to be included in our econometric analysis because of the unavailability of data. These factors include the recent revisions to the Lacey Act, the green building movement, and the formaldehyde standards in the United States. In order to combat illegal logging, the revised US Lacey Act not only bans logs and lumber, but also applies to all forest products. In fact, many Chinese wood products are manufactured from wood harvested in countries where illegal harvesting and other legal violations covered by the Lacey Act occur. For example, in the huge and rapidly expanding market for hardwood plywood, trade between China and the United States increased at an annual rate of 37 percent from 2002 to 2007, with the bulk of the timber being supplied from high-risk countries such as Russia, Papua New Guinea, Malaysia, Gabon, and the Solomon Islands (International Network for Environmental Compliance and Enforcement 2008). Therefore, this legislation will affect manufacturers and exporters who ship a variety of products made from wood, including furniture, plywood, and flooring made from illegally harvested wood, to the United States (Gregg and Porges 2008). Similar to the US Lacey Act, the Forest Law Enforcement, Governance and Trade (FLEGT), which aims to combat illegal logging and related trade outside the United States and will come into effect in 2012, could influence China's plywood and furniture exports to Europe. China's increasing dependence on timber product imports and anticipated future economic growth mean that Chinese demand is likely to continue to have dramatic social, environmental, and economic implications for forests and forestry people. These trends will continue to challenge the efforts of nongovernmental organizations and some governments to address illegal logging and trade and to establish sound institutions for governing forests in supplying countries (Sun et al. 2004).

Driven by the rising public awareness of global climate change, the cost and availability of nonrenewable energy resources, and the impact of the built environment on human health and natural environment, there is a shift to green building. Green building emphasizes taking advantage of renewable resources, for example, solar energy, rapidly renewable plant materials like bamboo and straw, and lumber from forests certified to be sustainably managed. The US green building movement could impact US demand for wood products in housing construction, interior decoration, and furniture, and thus affect Chinese hardwood plywood and furniture exports to the United States. Moreover, a problem identified in some Chinese plywood and low-priced furniture is high levels of formaldehyde. In order to reduce formaldehyde emissions from wood products and make healthier, greener, and more eco-friendly homes, a new law was recently signed into law the United States (O'Donnel 2010) limiting the amount of formaldehyde in composite wood products such as hardwood plywood, particleboard, and fiberboard. Similarly, most European nations have also passed laws that regulate formaldehyde. All these would lead to higher furniture and cabinet prices and may thus limit China's exports of plywood and furniture to the United States and Europe.

Like China's exports, apart from the economic factors we included in the models, there are some other possible factors that may affect China's demand for and supply of plywood, such as population growth, urbanization, construction demand, expanding wood processing capacity, and trade and foreign investment deregulation. Nonetheless, not all possible factors and explanatory variables can be included in the models. We had to reduce the variable selection based on, for example, the economic theory, limited degrees of freedom in the models, statistical characteristics, and availability of the data.

Because of data limitations, it was only possible to estimate relatively simple time-series models for Chinese plywood; however, as a result of rapid growth in the turbulent market, it was not meaningful to incorporate longer data spans or higher-frequency data in the estimation process. Many other researchers, for instance, Hondroyiannis and Papapetrou (1995), have argued that, despite its simplicity, the Engle–Granger methodology used in the empirical analysis also reveals some shortcomings. First, when there are more than two variables, there may be more than one cointegrating relationship and the Engle–Granger procedure, using residuals from a single relationship, cannot treat this possibility; thus the most important problem is that it does not give us the number of cointegrating vectors. Second, since the Engle–Granger approach relies on a two-step estimator, any error introduced in the first step is carried into the second step (Asteriou and Hall 2007). Nevertheless, we believe that the method we chose is the best available option for the research at hand, and statistically more elegant methods, such as the Johansen (1995) vector autoregressive model, could be used when statistical base allows the use (Toppinen 1998, Abildtrup et al. 1999).

Still, we hope that the present results from statistical models can serve as a useful reference for wood-processing companies, especially for plywood companies, government agencies, and public authorities acting as decision makers. China's dynamic economic growth and huge population-based market potential are reasons to expect that the China's plywood market will continue to grow and expand globally. This will encourage greater local and foreign investments in China's plywood market and therefore lead to the increased use of plywood in China. To that end, higher plywood prices may not necessarily become an obstacle to plywood consumption.

To achieve more satisfactory statistical results, future research should focus on efforts to gather more accurate data from China. Although our findings can be applicable to a range of topics, there is ample need for further analyses, models, and synthesis regarding the world's fastest growing plywood market.

Literature Cited

Abildtrup, J., F. Helles, P. Holten-Andersen, J. Fromholt Larsen, and B. Jellesmark Thorsen. 1999. Modern Time Series Analysis in Forest Products Markets. Forestry Sciences. Vol. 58. Kluwer Academic Publishers, Dordrecht, The Netherlands, 217 pp.

Adams, M. and H. O. Ma. 2002. China's plywood industry takes off. *ITTO Tropical Forest Update* 12/3:18–19.

Alberta China Office (ACO). 2008. In and out—New changes in China's furniture industry. http://www.docstoc.com/docs/14508621/Chinas-furniture-industry-VS-Canadian-furniture-industry. Accessed March 7, 2010.

Armington, P. S. 1969. A theory of demand for products distinguished by place of production. *IMF Staff Papers* 16:159–178.

Asteriou, D. and S. G. Hall. 2007. Applied Econometrics: A Modern Approach Using Eviews and Microfit. Rev. ed. Palgrave Macmillan, New York. 397 pp.

Buehlmann, U. and A. Schuler. 2009. The U.S. household furniture industry: Status and opportunities. *Forest Prod. J*. 59(9):20–28.

Buongiorno, J. 1979. Income and price elasticities of demand for sawnwood and wood-based panels: A pooled cross-section and time-series analysis. *Can. J. Forest Res*. 9(2):141–148.

Buongiorno, J. 1996. Forest sector modeling: A synthesis of econometrics, mathematical programming, and system dynamics methods. *Int. J. Forecasting* 12:329–343.

Buongiorno, J., S. Zhu, D. Zhang, J. Turner, and D. Tomberlin. 2003. The Global Forest Products Model: Structure, Estimation and Applications. Academic Press, San Diego, California. 301 pp.

Dickey, D. A. and W. A. Fuller. 1979. Distribution of the estimators for autoregressive time series with a unit root. *J. Am. Stat. Assoc*. 74: 427–431.

Engle, R. F. and C. W. J. Granger. 1987. Cointegration and error correction: Representation, estimation and testing. *Econometrica* 55: 251–276.

Ernst & Young. 2009. Eastern promises—Survey on the pulp and paper industry and the emerging markets. EYG No. ES0003. 2009 EYGM Limited. 43 pp. Special report available from Ernst & Young.

Gregg, J. and A. Porges. 2008. Amendments to the US Lacey Act: Implications for Chinese forest products exporters. http://www.illegal-logging.info/uploads/LaceyActBriefChinaEN.pdf. Accessed December 1, 2010.

Hänninen, R. 1998a. The law of one price in United Kingdom soft sawnwood imports: A cointegration approach. *Forest Sci*. 44(1): 17–23.

Hänninen, R. 1998b. Exchange rate changes and the Finnish sawnwood demand and price in the UK market. *Silva Fenn*. 32(1):61–73.

Hänninen, R. and A. Toppinen. 1999. Long-run price effects of exchange rate changes in Finnish pulp and paper exports. *Appl. Econ*. 31: 947–956.

Hänninen, R., A. Toppinen, and R. Toivonen. 2007. Transmission of price changes in sawnwood and sawlog markets of the new and old EU member countries. *Eur. J. Forest Res*. 126(1):111–120.

Helles, F., P. Holten-Andersen, J. Abildtrup, J. F. Larsen, and B. J. Thorsen. 1999. Introducing unit roots and cointegration. *In:* Modern Time Series Analysis in Forest Products Markets. J. Abildtrup, F. Helles, P. Holten-Andersen, J. Fromholt Larsen, and B. Jellesmark Thorsen (Eds.). Kluwer Academic Publishers, Dordrecht, The Netherlands. pp. 3–27.

Hetemäki, L., R. Hanninen, and A. Toppinen. 2004. Short-term forecasting models for the Finnish forest sector: Lumber exports and sawlog demand. *Forest Sci*. 50(4):461–472.

Hondroyiannis, G. and E. Papapetrou. 1995. An examination of Wagner's law for Greece: A cointegration analysis. *Public Finance/Finances Publiques* 50(1):67–79.

International Network for Environmental Compliance and Enforcement (INECE). 2008. Recent amendments to U.S. Lacey Act should help protect forests worldwide. http://www.inece.org/climate/ClimateComplianceAlert_LaceyAct.pdf. Accessed November 30, 2010.

Johansen, S. 1995. Likelihood-Based Inference in Cointegrated Vector Autoregressive Models. Oxford University Press Inc., New York. 267 pp.

Koutsoyiannis, A. 1977. Theory of Econometrics. 2nd ed. The Macmillan Press Ltd., London. 639 pp.

Li, H., J. Luo, and P. McCarthy. 2006. Economic transition and demand pattern: Evidence from China's paper and paperboard industry. *China Econ. Rev*. 17:321–336.

Ma, T. 2008. Interconnected forests: Global and domestic impacts of China's forestry conservation. A China environmental health project research brief. http://www.wilsoncenter.org/topics/docs/forestry_aug08.pdf. Accessed March 23, 2010.

O'Donnel, J. 2010. Furniture to be greener, but pricier. *USA Today*. http://www.usatoday.com/printedition/money/20100719/formaldehyde19_st.art.htm. Accessed December 1, 2010.

Rutten, L. and S. H. Tan. 2004. Reviving tropical plywood. ITTO Technical Series No. 20. International Tropical Timber Organization, Yokohama, Japan. 49 pp.

Schuler, A. and U. Buehlmann. 2008. Globalization and hardwood markets—The future offers opportunities and challenges. Northeast Utilization and Marketing Council Meeting and Training Session, June 2–5, 2008, Blacksburg, Virginia.

Solberg, B., A. Moiseyev, M. Kallio, and A. Toppinen. 2010. Impacts of increasing export tariffs and investment climate development in Russia on forest products markets. *Forest Pol. Econ*. 12(1):17–23.

Sun, X., E. Katsigris, and A. White. 2004. Meeting China's demand for forest products: An overview of import trends, ports of entry, and supplying countries, with emphasis on the Asia-Pacific Region. *Int. Forestry Rev*. 6(3–4):227–236.

Sun, X., L. Wang, and Z. Gu. 2005. China's timber market: An overview. http://www.rightsandtrade.org/~rightsa1/library/cwps/_docs/China.Brief.Overview.pdf. Accessed March 31, 2010.

Toppinen, A. 1998. Incorporating cointegration relations in a short-run model of the Finnish sawlog market. *Can. J. Forest Res*. 28(2):291–298.

United States International Trade Commission (USITC). 2008. Wood flooring and hardwood plywood: Competitive conditions affecting the U.S. industries. Investigation No. 332-487. USITC Publication 4032. http://www.usitc.gov/publications/332/pub4032.pdf. Accessed November 20, 2010.

Wan, M. 2009. Analysis of China's primary wood products market—Sawnwood and plywood. Master's thesis. University of Helsinki.

Wang, D. and W. Wu. 2000. Econometric analysis and forecasting of plywood in Taiwan. *Taiwan J. Forest Sci*. 15(3):379–390. (In Chinese.)

Wood Markets Report. 2010. China: Wood market trends—Strong rebound from short downturn in 2009. International Wood Markets Group Inc., Vancouver, British Columbia, Canada.