An Econometric Analysis of US Exports of Forest Products

Baodong Cheng
Bin Mei
Yang Wan

Abstract

Using cointegration analyses, we examined the econometric relationship between the US exports of selected forest products (roundwood, sawnwood, and paper and paper board) and a group of microeconomic factors. Overall, we found a positive impact of economic growth of importing countries on total US export of forest products, but mixed results for exchange rate risk and relative price by model specifications, by exchange rate risk measures, and across forest products.

The United States has abundant forest resources. Of the total 2,263 million acres of the country's territory, 751 million acres are forestlands and 514 million acres are productive timberlands (Smith et al. 2009). The forest products industry is one of the major manufacturing industries in the United States. It provides various employment opportunities and generates annual income in billions of dollars. Generally speaking, it is composed of the wood products manufacturing industry (North American Industrial Classification System [NAICS] 321), the paper manufacturing industry (NAICS 322), and the furniture and related product manufacturing industry (NAICS 337), with the paper manufacturing industry being the largest in terms of total output values. In recent years, the total value of shipments of the forest products averaged US$300 billion or about 10 percent of all manufacturing industries (US Bureau of Census 2012). In 2010 alone, the United States produced and consumed 340 and 330 million m^3 of roundwood,[1] respectively (Food and Agriculture Organization of the United Nations [FAO] 2010).

Besides domestic production and consumption, the United States has been an active wood exporter and importer in the world trade. In 2010, the United States exported and imported 11.8 and 1.4 million m^3 of industrial roundwood, respectively (FAO 2010). However, trade flows between exporting and importing countries have been changing over time (Table 1). A number of factors have been identified as the underlying drivers of these shifts including economic growth, comparative advantage, exchange rate risk, and trade resistance forces (Linnemann 1966). For example, Asia's economy has been developing rapidly since the 1980s. With this growing market, the focal point of global paper and paperboard production has transferred to Asian countries like China and Asia has been a net importer (Hujala et al. 2013). Meanwhile, major Asian currencies have been appreciating against the US dollar. From 2005 to 2013, Chinese Yuan has appreciated by more than 30 percent.[2] Accordingly, increasing trade flows from the United States to China have been observed. In 2009, the

[1] All wood (with or without bark, in its round form or split, roughly squared or in other form) removed from forests including wood recovered from natural, felling, and logging losses during the period, calendar year, or forest year. Roundwood is processed at primary manufacturing facilities into primary and secondary wood products. Industrial roundwood is all roundwood used for any purpose other than energy and comprises sawlogs that are processed into dimensional lumber, veneer logs peeled into plywood and panels, pulpwood chipped for pulp and paper products, and composite logs chipped for oriented strandboard panels. Fuelwood is converted into a variety of energy products (FAO 2010).

[2] Prior to July 2005, the exchange rate between the US dollar and Chinese Yuan was fixed by the Chinese government at 1:8.3. Thereafter, it was allowed to float according to the foreign exchange market. Currently, the ratio is around 1:6.2.

The authors are, respectively, Associate Professor, School of Economics and Management, Beijing Forestry Univ., Beijing, China (baodongcheng@163.com), and Visiting Scholar, Warnell School of Forestry and Natural Resources, Univ. of Georgia, Athens; Assistant Professor, Warnell School of Forestry and Natural Resources, Univ. of Georgia, Athens (bmei@uga.edu [corresponding author]); and Forest Economist, Forest2Market, Charlotte, North Carolina (ywan@forest2market.com). This paper was received for publication in May 2013. Article no. 13-00045.

Forest Prod. J. 63(7/8):224–231.
doi:10.13073/FPJ-D-13-00045

Table 1.—Five leading exporting and importing countries of selected forest products (2001 vs. 2009).[a]

Rank	2001 Roundwood	2001 Sawnwood	2001 Paper	2009 Roundwood	2009 Sawnwood	2009 Paper
Export	World (117,321)	World (109,703)	World (94,557)	World (95,507)	World (102,889)	World (105,222)
1	Russia (37,269)	Canada (36,339)	Canada (14,540)	Russia (21,700)	Canada (19,001)	Germany (12,295)
2	USA (11,412)	Sweden (10,818)	Finland (10,875)	USA (9,511)	Russia (16,200)	USA (11,277)
3	New Zealand (7,284)	Finland (8,135)	Germany (8,830)	New Zealand (8,767)	Sweden (12,271)	Sweden (9,867)
4	Malaysia (5,380)	Russia (7,730)	Sweden (8,733)	Germany (4,205)	Germany (9,810)	Finland (9,644)
5	France (4,978)	Austria (6,285)	USA (8,355)	Malaysia (4,165)	Austria (5,799)	Canada (9,526)
Import	World (120,345)	World (112,854)	World (96,345)	World (91,558)	World (94,254)	World (102,599)
1	China (18,459)	USA (35,226)	USA (15,534)	China (28,653)	USA (15,428)	USA (10,453)
2	Japan (13,911)	Japan (8,980)	China (9,803)	Austria (8,036)	China (11,006)	Germany (9,742)
3	Finland (11,869)	UK (7,876)	Germany (9,494)	Germany (7,199)	Germany (5,649)	UK (7,018)
4	Sweden (9,505)	Italy (7,785)	UK (7,028)	Korea (5,165)	Japan (5,568)	France (5,033)
5	Austria (7,630)	China (5,724)	France (5,848)	Canada (4,555)	Italy (5,567)	China (5,011)

[a] Numbers in parentheses are in thousand cubic meters for roundwood and sawnwood, and in thousand tons for paper and paperboard. The United States is also a major exporting country (among top 10) of sawnwood. Data source: ''FAO Yearbook of Forest Products'' (FAO 2010).

United States exported 1.6 million m^3 of industrial roundwood to China, an 80 times increase from 0.04 million m^3 in 2001.

Given the boom of low-income economies, the evolving globalization of forest products manufacturing, and the volatility of foreign exchange market, in this article we aim to examine the impact of exchange rate volatility on US export of roundwood, sawnwood, and paper and paperboard via advanced time series analysis. To accomplish the overall objective, two specific objectives are pursued. First, the US forest products export market is qualitatively reviewed. Trade flows between leading exporting and importing countries are compared, and the drivers of these trade flows are discussed. The market shares and trends of selected forest products are summarized. Second, the US forest products export market is quantitatively analyzed with error-correction models. The results reveal some variations, across model specifications and commodities, in the impact of major macroeconomic factors on the trade flows. This study can expand our knowledge in the dynamics of international trade of forest products.

US Export of Forest Products

The United States is a global leading exporter of forest products. As shown in Figure 1, the United States maintained a consistent share around 12 percent of the world total export value of forest products from 1973 to 2009. Specifically, industrial roundwood, sawnwood, and paper and paperboard accounted for 22, 9, and 9 percent of the world total, respectively. The US export share of paper and paperboard has remained relatively stable, whereas US export shares for industrial roundwood and sawnwood have been declining in the last 20 years. This is possibly caused by local supply restrictions coupled with changes in foreign markets. For example, the enactment of the Endangered Species Act and subsequent amendments have reduced timber harvest in the United States, particularly in the Pacific Northwest region, and thus reduced wood supply. On the other hand, Japan, a major trade partner of the United States, established a new housing quality assurance law after the 1995 Kobe earthquake, which drove the demand for high-quality lumber in the Japanese housing market. Scandinavian producers have been successful in entering this market and taking market shares. As a result, the market share of others has been shrinking.

The export value of the three products combined accounted for an average 64 percent of the total US export value of forest products from 1973 to 2009 (Fig. 2). The shares of industrial roundwood and sawnwood exports have been declining moderately in the past 20 years, but the share of paper and paperboard has been increasing dramatically. These trends can be explained from the efficiency and global competitiveness perspective. For example, the employment in the paper industry has been downsizing more than the industry output as a result of industry consolidation and closure of outdated and less efficient paper mills (Mei and Sun 2008, Woodall et al. 2011). The net effect has been a significant improvement of labor productivity of the US paper producers. Since 2001, the per employee output in the US paper industry has risen by more than 40 percent, and therefore the United States has gained the comparative advantage in paper and paperboard manufacturing (Woodall et al. 2011).

In sum, for all three forest products, Europe and North America have historically been net exporters. For industrial roundwood, Asia-Pacific has been a net importer. The

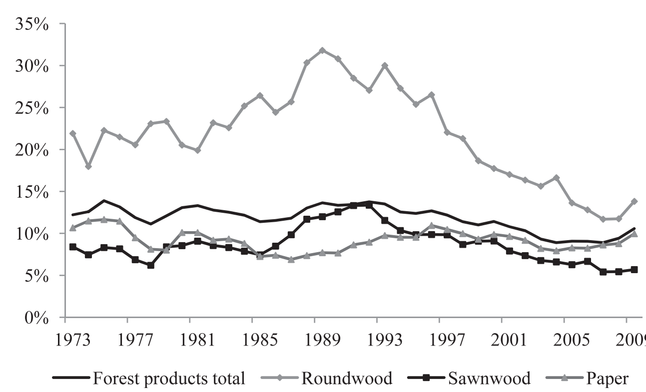

Figure 1.—US share of the world total export value of forest products. In 2009, the world had a total export of US$789 billion of all forest products, US$9.8 billion of industrial roundwood, US$24.0 billion of sawnwood, and US$92.3 billion of paper and paperboard.

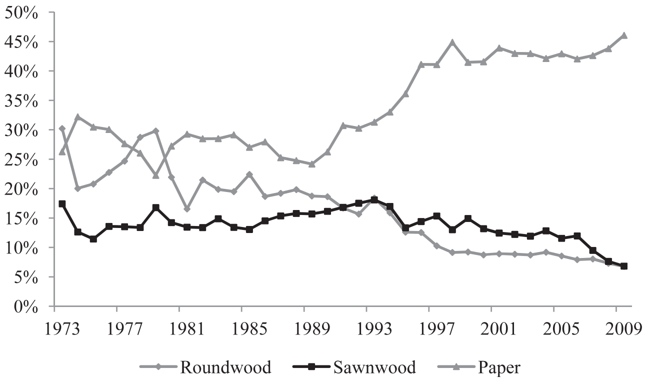

Figure 2.—Share of the US total export value of forest products. In 2009, the United States had a total export of US$20.0 billion of all forest products, US$1.4 billion of industrial roundwood, US$1.4 billion of sawnwood, and US$9.2 billion of paper and paperboard.

United States has been actively trading with Canada, Asia-Pacific, and Europe. For sawnwood, Africa and Asia-Pacific have been net importers. The United States has been actively trading with Canada, Mexico, and Asia-Pacific. For paper and paperboard, Asia-Pacific, Latin America and the Caribbean, and Africa have been net importers. The United States has been actively trading with Canada, Mexico, Asia-Pacific, and Europe. US trade flows of the three products in 2001 versus 2009 are shown in Table 2.

Literature Review

There are abundant studies in the international trade of forest products. Using gravity models (Linnemann 1966),[3] a number of studies investigated bilateral trade flows of forest products. Kangas and Niskanen (2003) studied trade patterns between the European Union and Eastern European access candidates. Polyakov and Teeter (2007) modeled interregional trade of roundwood products in the US South. Zhang and Li (2009) explored determinants of China's wood products trade from 1995 to 2004. Hujala et al. (2013) estimated augmented gravity models of trade flows for chemical pulp and recovered paper exports. In short, a variety of explanatory variables have been selected specific to each trade and different results have been founded for different regions or products.

Another school of researchers have examined the impact of exchange rate volatility on international trade flows, controlling for other macroeconomic factors. Nevertheless, with the null hypothesis that unanticipated changes in exchange rates should discourage trade flows, mixed results have been found in previous research. For instance, Arize (1997), Sun and Zhang (2003), and Zhang and Buongiorno (2010) found a negative impact of exchange rate volatility on export quantity, whereas Asseery and Peel (1991), Dellas and Zilberfarb (1993), and Broll and Eckwert (1999) found a positive relationship. The contradictory findings may be due to different investigation levels (e.g., aggregate vs. industry-specific trade flows or bilateral vs. overall trade flows), different measures of exchange rate risk,[4] different econometric specifications and estimation methods,[5] or all combined. With aggregate analyses, it is implied that the effect is uniform for all products, which is a very restrictive constraint. This research relaxes this assumption by focusing specifically on US exports of selected forest products and aims to provide empirical evidence at a more disaggregate level using more sophisticated time series analysis.

Methods and Data

Two measures of exchange rate volatility

Volatility is a very important concept in theoretical and practical economic studies. The means of measuring volatility have evolved over time with new advances in econometrics. Overall, there are two broad ways to estimate exchange rate volatility in the literature. One way is to use a moving average (MA) of sample standard deviations (e.g., Sun and Zhang 2003). The MA is calculated as in Equation 1

$$V_t = \sqrt{\frac{1}{m}\sum_{i=1}^{m}(\ln R_{t+i-1} - \ln R_{t+i-2})^2} \tag{1}$$

where V is volatility, m is the order of moving average, and R is the exchange rate of the US dollar. The other way is to use conditional standard deviations obtained from the Generalized Autoregressive Conditional Heteroskedasticity (GARCH) model (e.g., Zhang and Buongiorno 2010). For most financial time series, a GARCH(1,1) model (Eq. 2) is sufficient

$$\begin{aligned} R_t &= c + e_t, \quad e_t|F_{t-1} \sim N(0, h_t) \\ h_t &= \omega + \alpha e_{t-1}^2 + \beta h_{t-1} \end{aligned} \tag{2}$$

where e_t is a real-valued discrete-time stochastic process, F_t is the information set containing all available information up to time t, h_t is the conditional, time-varying variance of the exchange rate, and c, ω, α, and β are parameters to be estimated, with $\alpha \geq 0$, $\beta \geq 0$, and $\alpha + \beta < 1$ (Bollerslev 1986, Lamoureux and Lastrapes 1990). Parameter c can be interpreted as the mean of the exchange rate, and α and β describe how conditional variance depends on past sample and conditional variances. The model can be estimated using the maximum likelihood method.

Both methods have their strengths and weaknesses. The MA measure is easy to calculate, but the choice of the MA order is arbitrary and the sample size has to be sacrificed with the calculation. The GARCH method captures volatility clustering, reveals the evolvement of volatilities over time, and is parsimonious and flexible. In this study, both measures are used for a comparison purpose.

[3] Gravity models are widely used to examine trade flows between two countries. Common explanatory variables include gross domestic product, population, geographical distance, and trade preference factors. A detailed discussion of gravity models is beyond the scope of this study but can be found in Hujala et al. (2013).

[4] Bahmani-Oskooee and Hegerty (2007) summarized various measures of exchange rate volatility. The most commonly used are moving average of standard deviations and conditional standard deviation from Autoregressive Conditional Heteroskedasticity models.

[5] Early research used ordinary least squares, whereas most recent research applied more advanced econometric techniques such as time series and panel-data analyses.

Table 2.—US exports of selected forest products (2001 vs. 2009).[a]

Rank	2001			2009		
	Roundwood	Sawnwood	Paper	Roundwood	Sawnwood	Paper
1	Canada (6,555)	Canada (1,245)	Canada (2,247)	Canada (3,559)	Mexico (509)	Canada (2,345)
2	Japan (3,343)	Japan (510)	Mexico (1,175)	China (1,682)	Canada (500)	Mexico (2,221)
3	Korea (581)	Mexico (494)	China (662)	Korea (1,513)	Japan (216)	China (595)
4	China (176)	China (396)	Japan (432)	Japan (538)	China (104)	Japan (463)
5	Germany (110)	Spain (289)	Italy (251)	Germany (330)	Spain (67)	Italy (326)

[a] Numbers in parentheses are in thousand cubic meters for roundwood and sawnwood, and in thousand tons for paper and paperboard. Data source: ''FAO Yearbook of Forest Products'' (FAO 2010).

Model and variable specifications

Although there are a variety of different models of the determinants of trade flows, recent studies have used more parsimonious export demand models with the export volume expressed as a function of the importer's income, relative export price, and exchange rate volatility (Bahmani-Oskooee and Hegerty 2007). Despite its simplicity, the export demand model is capable of estimating the substitution effect and income effect based on the consumer theory. Accordingly, econometric specifications in this study are based on the following specification:

$$\ln E_t = \beta_0 + \beta_1 \ln G_t + \beta_2 P_t + \beta_3 \ln V_t + \varepsilon_t \qquad (3)$$

where E is the total trade volume or value, G is the world purchasing power as approximated by the world gross domestic product (GDP), P is the relative export price (i.e., US export price divided by world export price), and ε is the error term. (Logarithm transformation is not applied to P because it is a relative price and can be less than 1.) Importer's income has an expected positive impact, whereas relative export price has an expected negative impact on the export volume, ceteris paribus. For the exchange rate risk, it should reduce trade flows in the absence of any hedging mechanisms (Ethier 1973). Nonetheless, sufficient forward and futures markets may reduce this effect (Clark 1973). In the real world, forward and futures markets are not perfect, and mixed empirical findings were found between international trade flows and exchange rate volatility (e.g., Broll and Eckwert 1999, Sun and Zhang 2003).

The export demand model can be estimated by ordinary least squares (OLS). However, the standard OLS estimation ignores the statistical properties of time series and the dynamic nature of international trade flows. To incorporate both short-run and long-run effects, advanced time series analysis is needed. The first step is to test the stationarity of each individual time series. If a time series is not stationary, it has to be differenced before any modeling. If a nonstationary time series becomes stationary after being differenced n times, it is said to be integrated of order n and denoted as $I(n)$ (Tsay 2005).

When a group of $I(1)$ time series is considered, the fact that a linear combination of those individual time series may be in fact stationary is called cointegration (Engle and Granger 1987). Two general methods are used to analyze cointegrated time series, the Johansen (1988) vector error-correction model (VECM) and the Engle and Granger (1987) two-step error-correction method (TSECM). A VECM with m cointegrating factors can be represented as follows (Johansen 1991):

$$\Delta y_t = \mu_t + \Pi y_{t-1} + \sum_{i=1}^{p-1} \Phi_i^* \Delta y_{t-i} + \xi_t \qquad (4)$$

where $\Pi = -I + \sum_{i=1}^{p} \Phi_i$, $\Phi_i^* = -\sum_{j=i+1}^{p} \Phi_j$, and Φ's are coefficient matrices of the following vector autoregressive model (VAR) of order p

$$y_t = \mu + \Phi_1 y_{t-1} + \Phi_2 y_{t-2} + \cdots + \Phi_p y_{t-p} + a_t \qquad (5)$$

In Equation 5, y is a $k \times 1$ vector of time series and Φ's are $k \times k$ coefficient matrices. Matrix Π can be decomposed into $\alpha\beta'$, where α and β are $k \times m$ ($m < k$) full-rank matrices. The time series $\beta' y_{t-1}$ is unit root stationary and known as the error-correction (EC) term, the columns of β are cointegrating vectors of y_{t-1}, and α denotes the speed to restore equilibrium.

With respect to Equation 3, the corresponding VECM can be stated as

$$\begin{aligned}\Delta \ln E_t = {} & \alpha_0 + \alpha_1 EC_{t-1} + \sum_{i=1}^{q} \gamma_{E,i} \Delta \ln E_{t-i} \\ & + \sum_{i=1}^{q} \gamma_{G,i} \Delta \ln G_{t-i} + \sum_{i=1}^{q} \gamma_{P,i} \Delta P_{t-i} \\ & + \sum_{i=1}^{q} \gamma_{V,i} \Delta \ln V_{t-i} + e_t \end{aligned} \qquad (6)$$

where γ's reflect short-run effects or immediate responses to previous changes. Whereas, with the TSECM, the residuals from Equation 3 are first obtained and then used as the error-correction term in a dynamic equation similar to Equation 6.

Data

The data used in this study come from various sources. Annual export volume and value data of industrial roundwood, sawnwood, and paper and paperboard are from the ''FAO Yearbook of Forest Products'' (FAO 2010). Industrial roundwood is used in the production of goods and services other than fuel. Sawnwood is produced from roundwood by sawing and chipping processes. Paper and paperboard represents newsprint, printing and writing paper, and other paper and paperboard. These definitions are based on those contained in ''Classification and Definitions of Forest Products'' (FAO 1982). Export price (unit value) is export value divided by volume. The relative price is defined as the ratio of the US export price to the world

Table 3.—Definitions and descriptive statistics of the key variables (1973 to 2009).[a]

Variable	Definition	Mean (SD) values		
		Roundwood	Sawnwood	Paper
Export value (US$ billion)	Total dollar value of US export to the rest of the world	1.733 (0.632)	1.561 (0.717)	4.244 (2.719)
Export volume (m^3 million)	Total volume of US export to the rest of the world	18.085 (6.401)	5.772 (1.968)	6.255 (3.017)
World GDP (US$ trillion)	World gross domestic product	24.501 (15.681)	24.501 (15.681)	24.501 (15.681)
Relative export price	Ratio of US export price over world export price	1.442 (0.230)	1.442 (0.23)	0.960 (0.132)
Exchange rate volatility	Conditional standard deviation from GARCH(1,1)	0.062 (0.016)	0.062 (0.016)	0.062 (0.016)
	Moving average of standard deviation	0.061 (0.026)	0.061 (0.026)	0.061 (0.026)

[a] GDP = gross domestic product; GARCH = Generalized Autoregressive Conditional Heteroskedasticity.

Table 4.—Results from the Augmented Dickey-Fuller (ADF) test.[a]

Variable[b]	Roundwood		Sawnwood		Paper	
	Level	First differencing	Level	First differencing	Level	First differencing
E (volume)	0.705	0.000	0.913	0.000	0.145	0.000
E (value)	0.404	0.026	0.951	0.001	0.281	0.000
G	0.347	0.111	0.347	0.111	0.347	0.111
P	0.002	0.000	0.143	0.000	0.048	0.000
V (GARCH)	0.545	0.000	0.545	0.000	0.545	0.000
V (MA)	0.838	0.003	0.838	0.003	0.838	0.003

[a] Null hypothesis: Series has a unit root. Reported are *P* values from the ADF test with a constant and a trend. The results are generally robust with respect to model specifications (i.e., with or without a constant and/or a trend).
[b] GARCH = Generalized Autoregressive Conditional Heteroskedasticity; MA = moving average.

export price. The aggregation of forest products trade volumes are based on relevant numerical codes used in the United Nations Standard International Trade Classification (SITC) system and in the Harmonised System (HS) of the world Customs Organization (FAO 2010).[6] For trade values, annual exchange rates are used to convert local currency units to US dollars.

The GDP data are available from the World Bank (The World Bank 2013). The exchange rate is approximated by the broad index of the US dollar, a weighted average of the foreign exchange values of the US dollar against the currencies of a large group of major US trading partners. The index weights change over time and are derived from US export shares and from US and foreign import shares. The broad index is reported by the Federal Reserve Board (Federal Reserve Bank of St. Louis 2012). The definitions and descriptive statistics of the key variables are presented in Table 3.

Results

To understand the short-run market dynamics, whether there is a long-run equilibrium and cointegration relationship needs to be tested first. Table 4 shows the results from the Augmented Dickey-Fuller test (Dickey and Fuller 1979). Using the raw data, the null hypothesis of a unit root cannot be rejected, indicating that the data are not stationary. However, after the first differencing, the null hypothesis should be rejected at the 5 percent level (or at the 15% level for the GDP), indicating the data are integrated of order one. Via the trace and maximum eigenvalue tests (Johansen 1988, 1991), one cointegrating relation is identified.

Results from the error-correction models are presented in Table 5. For roundwood export volume, exchange rate volatility shows a negative impact in the short-run but it is only significant with the GARCH measure in the VECM model. Other variables have no significant loadings. For roundwood export value, the exchange rate volatility does not have a significant impact but the world GDP has a significant positive impact. A 1 percent increase in world GDP results in a 1.07 to 1.29 percent increase in US export value of roundwood. The error-correction term is only significant for the VECM model with GRACH measure. However, the magnitude is still trivial. Therefore, the effect of long-run correction to the equilibrium is weak.

For sawnwood export volume, exchange rate volatility has no significant impact but the world GDP has a substantial leverage effect. A 1 percent increase in world GDP leads to a 1.71 to 1.93 percent increase in US export volume of sawnwood. For sawnwood export value, exchange rate volatility only shows significant but mixed effects in the TSECM model. The elasticity of world GDP on export value of sawnwood is stronger at 1.98 to 2.86. In addition, there is some evidence of a negative correlation of sawnwood export over time, implying some cyclical patterns of trade flows. Most of the coefficients on the error-correction term are significant but with mixed signs. The magnitudes are relatively small. Overall, it appears that there is instability of sawnwood export.

For paper and paperboard export volume, exchange rate volatility only has a significant loading in the TSECM model with the MA measure. The world GDP shows a significant positive effect except for the VECM model with the MA measure. The elasticity of world GDP on export volume of paper and paperboard ranges from 1.30 to 1.88. For paper and paperboard export value, all variables have similar loadings

[6] Data provided by countries using different units or systems of measurement are converted to a standard set of metric units. The conversion coefficients can be found in ''FAO Yearbook of Forest Products.'' A detailed discussion about the quality of FAO data can be found in Kasnakoglu and Mayo (2004).

Table 5.—Parameter estimation of the export model of major forest products.[a]

	Roundwood				Sawnwood				Paper			
	VECM		TSECM		VECM		TSECM		VECM		TSECM	
	A	B	A	B	A	B	A	B	A	B	A	B
Volume												
C	−0.01 [0.75]	−0.02 [0.65]	−0.01 [0.76]	−0.01 [0.76]	−0.14 [0.00]	−0.13 [0.01]	−0.14 [0.01]	−0.15 [0.00]	−0.04 [0.42]	0.02 [0.65]	−0.06 [0.22]	−0.06 [0.16]
EC	0.03 [0.01]	0.07 [0.28]	0.03 [0.77]	0.06 [0.66]	0.18 [0.10]	0.12 [0.08]	0.17 [0.16]	0.37 [0.04]	−0.10 [0.31]	−0.37 [0.01]	0.45 [0.03]	0.61 [0.00]
$\Delta \ln E_{t-1}$	−0.01 [0.96]	0.11 [0.66]	0.18 [0.41]	0.17 [0.48]	[0.04]	−0.30 [0.24]	−0.20 [0.38]	−0.39 [0.14]	−0.26 [0.33]	0.16 [0.55]	−0.28 [0.26]	−0.40 [0.08]
$\Delta \ln G_{t-1}$	−0.05 [0.92]	0.08 [0.88]	−0.04 [0.93]	−0.05 [0.92]	1.80 [0.00]	1.71 [0.00]	1.75 [0.00]	1.93 [0.00]	1.30 [0.03]	0.26 [0.65]	1.67 [0.01]	1.88 [0.00]
ΔP_{t-1}	−0.19 [0.26]	0.04 [0.81]	0.18 [0.14]	0.19 [0.12]	−0.06 [0.77]	0.00 [0.99]	0.18 [0.33]	0.10 [0.59]	−0.09 [0.78]	−0.19 [0.49]	−0.05 [0.86]	−0.06 [0.82]
$\Delta \ln V_{t-1}$	−0.19 [0.04]	−0.04 [0.78]	−0.02 [0.76]	−0.01 [0.95]	−0.08 [0.42]	−0.15 [0.20]	0.11 [0.13]	−0.12 [0.28]	0.16 [0.23]	−0.14 [0.20]	0.07 [0.39]	−0.28 [0.01]
R^2	0.32	0.14	0.10	0.10	0.42	0.31	0.31	0.34	0.18	0.40	0.29	0.43
F-stat	2.69	0.88	0.64	0.65	4.00	2.48	2.55	2.88	1.27	3.69	2.26	4.26
Value												
C	−0.07 [0.18]	−0.08 [0.13]	−0.07 [0.19]	−0.08 [0.14]	−0.14 [0.01]	−0.09 [0.09]	−0.15 [0.00]	−0.15 [0.00]	−0.01 [0.75]	0.01 [0.87]	−0.03 [0.34]	−0.04 [0.27]
EC	0.01 [0.46]	−0.03 [0.50]	0.03 [0.76]	−0.01 [0.94]	0.15 [0.02]	−0.11 [0.07]	0.34 [0.00]	0.43 [0.00]	−0.06 [0.61]	−0.13 [0.26]	0.22 [0.13]	0.29 [0.07]
$\Delta \ln E_{t-1}$	0.21 [0.35]	0.06 [0.81]	0.19 [0.42]	0.08 [0.74]	−0.60 [0.02]	−0.27 [0.16]	−0.39 [0.02]	−0.56 [0.00]	−0.13 [0.56]	−0.11 [0.62]	−0.28 [0.12]	−0.43 [0.02]
$\Delta \ln G_{t-1}$	1.10 [0.10]	1.27 [0.06]	1.07 [0.11]	1.29 [0.06]	2.70 [0.00]	1.98 [0.01]	2.64 [0.00]	2.86 [0.00]	1.13 [0.05]	0.89 [0.14]	1.58 [0.00]	[0.00]
ΔP_{t-1}	−0.10 [0.55]	0.09 [0.60]	−0.01 [0.96]	0.00 [0.98]	0.26 [0.12]	0.15 [0.41]	0.16 [0.30]	0.20 [0.20]	−0.32[0.05]	−0.41 [0.02]	−0.26 [0.07]	−0.22 [0.13]
$\Delta \ln V_{t-1}$	0.07 [0.39]	−0.12 [0.32]	0.08 [0.34]	−0.13 [0.30]	−0.07 [0.52]	−0.20 [0.12]	0.14 [0.05]	−0.29 [0.01]	0.07 [0.28]	−0.10 [0.23]	0.06 [0.29]	−0.17 [0.04]
R^2	0.28	0.28	0.27	0.27	0.42	0.39	0.53	0.49	0.40	0.45	0.44	0.49
F-stat	2.17	2.20	2.05	2.07	3.98	3.56	6.19	5.48	3.75	4.58	4.46	5.39

[a] Columns A and B denote exchange volatility measured from the Generalized Autoregressive Conditional Heteroskedasticity (GARCH)(1,1) model and the moving average (MA) model, respectively. P values are presented in brackets. VECM and TSECM refer to vector error-correction model and two-stage error-correction model, respectively. Logarithm transformation is applied to all variables except for P because it is a relative price and can be less than 1.

except for relative export price. The substitution effect is statistically significant. Economically, doubling US export price of paper and paperboard will reduce its export value by 0.22 to 0.41 percent. The results on the error-correction term are mixed and moderate in magnitude.

In a nutshell, changes in world GDP tend to be the most important factor that affects changes in both export volume and value of the selected forest products in the short-run. The other effects are mixed across export indicators, forest products, model specifications, and measures of exchange rate risk.

Discussion and Conclusions

Using cointegration analyses, we examine the econometric relationship between US exports of selected forest products and a group of microeconomic factors. Overall, we find some evidence that economic growth of the importing countries have a positive impact on US export volume and value in the short-run. The marginal impact is stronger for export value because the export volume represents the aggregate production decisions made by forest products producers, whereas the export values incorporates market conditions like output prices and exchange rate levels in addition to the total units produced. At the product level, the impact of exchange rate volatility varies by model specifications, by exchange rate volatility measures, and across forest products. For example, the impact of exchange rate risk on roundwood export volume is significant in the VECM model with the GARCH measure but not the MA measure. Therefore, we caution against interpreting previous empirical findings without digging into the technical details.

Generally speaking, results for roundwood export are less significant and uniform than those for sawnwood and paper and paperboard. This may be because roundwood products are far less homogenous than the other two products. For softwood roundwood only, three products (pulpwood, chip-n-saw, and sawtimber) can be classified and their prices differ substantially. As of the second quarter of 2013, softwood pulpwood, chip-n-saw, and sawtimber were priced at US$9.55/ton, US$16.17/ton, and US$24.59/ton, respectively, in the US South (Norris Foundation 2013). Timber price also varies by species. Oak wood usually has a premium for its strength and hardness and is primarily used for furniture making and flooring, timber frame buildings, and veneer production. Without detailed information about the composition of roundwood export, it is less precise to estimate the export demand model.

Using futures and forwards to hedge against exchange rate risk is not uncommon in doing international businesses. With some cost upfront, exchange rate risk can be minimized to certain extent. However, futures and forwards markets can be incomplete. Traders and investors are drawn to markets with high liquidity because these markets offer better opportunity for profiting. The emerging markets usually have very low volume and liquidity and need to gain traction before becoming competitive with other established contracts.[7] Wong (2013) showed that a firm's optimal production and hedging decisions relied critically on the degree of forward market incompleteness and correlation structure of the output price and exchange rate risk. As such, the true marginal effect of exchange rate risk on exports should be more accurately captured if the hedging effect is controlled for. In addition, trade policies and tariff can influence bilateral trade flows. It's widely recognized that the Canada–US softwood lumber dispute has largely affected Canada's export of softwood lumber to the United States (Zhang and Sun 2001). Future research can include these factors and examine trade flows of forest products at a finer scale.

[7] The Chicago Mercantile Exchange (CME) Group, the largest regulated currency futures marketplace in the world, provides 49 currency futures contracts with over US$100 billion in daily liquidity. Smaller exchanges exist worldwide, including NYSE Euronext, the Tokyo Financial Exchange (TFX), and the Brazilian Mercantile and Futures Exchange (BM&F). The G10 (Belgium, Canada, France, Germany, Italy, Japan, The Netherlands, Sweden, the United Kingdom, and the United States), the E-Mini (1/5 the size of standard currency futures contracts), and the E-Micro (1/10 the size of standard currency futures contracts) contracts are the most actively traded and have the highest liquidity.

Acknowledgments

Part of this research was funded by Beijing Higher Education Young Elite Teacher Project (BJQNYC201339) and National Natural Science Foundation of China (71203011). The authors thank Mr. Brandon Hatchett for his help on the data collection.

Literature Cited

Arize, A. C. 1997. Conditional exchange-rate volatility and the volume of foreign trade: Evidence from seven industrialized countries. *South. Econ. J.* 64(1):235–254.

Asseery, A. and D. A. Peel. 1991. The effects of exchange rate volatility on exports: Some new estimates. *Econ. Lett.* 37(2):173–177.

Bahmani-Oskooee, M. and S. W. Hegerty. 2007. Exchange rate volatility and trade flows: A review article. *J. Econ. Studies* 34(3):211–255.

Bollerslev, T. 1986. Generalized autoregressive conditional heteroskedasticity. *J. Econom.* 31(3):307–327.

Broll, U. and B. Eckwert. 1999. Exchange rate volatility and international trade. *South. Econ. J.* 66(1):178–185.

Clark, P. B. 1973. Uncertainty, exchange risk, and level of international trade. *West. Econ. J.* 11(3):302–313.

Dellas, H. and B. Z. Zilberfarb. 1993. Real exchange rate volatility and international trade—A reexamination of the theory. *South. Econ. J.* 59(4):641–647.

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(366):427–431.

Engle, R. F. and C. W. J. Granger. 1987. Co-integration and error correction: Representation, estimation, and testing. *Econometrica* 55(2):251–276.

Ethier, W. 1973. International trade and forward exchange market. *Am. Econ. Rev.* 63(3):494–503.

Federal Reserve Bank of St. Louis. 2012. Federal Reserve economic data. http://research.stlouisfed.org/fred2/series/TWEXB. Accessed May 1, 2013.

Food and Agriculture Organization of the United Nations (FAO). 1982. Classification and definitions of forest products. FAO, Rome.

Food and Agriculture Organization of the United Nations (FAO). 2010. FAO yearbook of forest products. FAO, Rome.

Hujala, M., H. Arminen, R. C. Hill, and K. Puumalainen. 2013. Explaining the shifts of international trade in pulp and paper industry. *Forest Sci.* 59(2):211–222.

Johansen, S. 1988. Statistical analysis of cointegration vectors. *J. Econ. Dyn. Control* 12(2–3):231–254.

Johansen, S. 1991. Estimation and hypothesis testing of cointegration vectors in Gaussian vector autoregressive models. *Econometrica* 59(6):1551–1580.

Kangas, K. and A. Niskanen. 2003. Trade in forest products between European Union and the Central and Eastern European access candidates. *Forest Pol. Econ.* 5(3):297–304.

Kasnakoglu, H. and R. Mayo. 2004. FAO statistical data quality framework: A multi-layered approach to monitoring and assessment.

In: Conference on Data Quality for International Organizations, May 27–28, 2004, Wiesbaden, Germany. 16 pp.
Lamoureux, C. G. and W. D. Lastrapes. 1990. Persistence in variance, structural change, and the GARCH model. *J. Bus. Econ. Stat*. 8(2):225–234.
Linnemann, H. 1966. An Econometric Study of International Trade Flows. North-Holland, Amsterdam, The Netherlands.
Mei, B. and C. Sun. 2008. Assessing time-varying oligopoly and oligopsony power in the U.S. paper industry. *J. Agric. Appl. Econ*. 40(3):927–939.
Norris Foundation. 2013. Timber Mart-South. Warnell School of Forestry and Natural Resources, University of Georgia, Athens.
Polyakov, M. and L. Teeter. 2007. Modeling pulpwood trade within the United States South. *Forest Sci*. 53(3):414–425.
Smith, W. B., P. D. Miles, C. H. Perry, and S. A. Pugh. 2009. Forest resources of the United States, 2007: A technical document supporting the Forest Service 2010 RPA assessment. General Technical Report WO-78. USDA Forest Service, Washington, D.C. 349 pp.
Sun, C. and D. Zhang. 2003. The effects of exchange rate volatility on U.S. forest commodities exports. *Forest Sci*. 49(5):807–814.
The World Bank. 2013. The World Bank open data. http://data.worldbank.org/indicator/NY.GDP.MKTP.CD. Accessed May 1, 2013.
Tsay, R. S. 2005. Analysis of Financial Time Series. John Wiley & Sons, Hoboken, New Jersey. 640 pp.
US Bureau of Census. 2012. Economic census, manufacturing, subject series, general summary. EC02-31SG-1. Department of Commerce, Washington, D.C.
Wong, K. P. 2013. International trade and hedging under joint price and exchange rate uncertainty. *Int. Rev. Econ. Financ*. 27(0):160–170.
Woodall, C. W., P. J. Ince, K. E. Skog, F. X. Aguilar, C. E. Keegan, C. B. Sorenson, D. G. Hodges, and W. B. Smith. 2011. An overview of the forest products sector downturn in the United States. *Forest Prod. J*. 61(8):595–603.
Zhang, D. and Y. Li. 2009. Forest endowment, logging restrictions, and China's wood products trade. *China Econ. Rev*. 20(1):46–53.
Zhang, D. and C. Sun. 2001. U.S.-Canada softwood lumber trade disputes and lumber price volatility. *Forest Prod. J*. 51(4):21–27.
Zhang, S. and J. Buongiorno. 2010. Effects of exchange rate volatility on export volume and prices of forest products. *Can. J. Forestry Res*. 40(11):2069–2081.