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economics

From Deficit to Surplus: An Econometric Analysis of US Trade Balance in Forest Products

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Although the US trade deficit has persisted since 1975, the country changed in 2009 from a net importer to a net exporter of forest products, emerging as the world's largest exporter of forest products. Drawing on recent data, we model the real dollar value of US exports, imports, and the trade balance in forest products to identify factors likely to explain this shift. We find that US dollar depreciation and the purchasing power of the rest of the world have positively affected US exports, while recessions and the implementation of the Lacey Act Amendment of 2008 have negatively affected US imports, the latter reducing the total value of imports by 24%. Furthermore, a temporary (2007–2010) contraction in the consumption of forest products domestically led to a shift in the trade balance.

Keywords: US trade balance, forest products, economic recession, export effort, Lacey Act Amendment (LAA) of 2008

The forest products industry is among the most important resource-based industries in the United States. As the nation gradually depleted its natural forests in the 19th century, as resource conservation just started, and as planted forests had yet to emerge as a significant component of the timberland base, it became a net forest products importer for the first time in 1913. This situation continued for nearly a century (Howard and Westby 2013). More recently, between 1961 and 2008, the United States was the world's largest importer of forest products, and its trade deficit in forest products generally grew over time (Figure 1). However, the country changed from a net importer to a net exporter in the total value of forest products in 2009 and has newly emerged as the world's largest exporter of forest products in dollar terms since then (Table 1). This is in contrast to the overall trend in the US trade balance in manufactured goods as a whole, for which a large trade deficit has existed since 1975 and persisted in 2014 (US Census Bureau 2016).

As a guide for a complete understanding of the causal mechanisms behind the recent shift in the US forest products trade balance, the extant literature offers little. We endeavor to fill this void by identifying several factors that we hypothesize can explain the temporal dynamics of the total value of traded US forest products. With annual data spanning 1961 to 2014, we offer statistical evidence for why the US trade position in forest products has been altered so significantly in the last decade and evaluate whether this alteration signals a more permanent shift. Key variables in our analysis are measures of permanent and transient factors that are hypothesized to drive imports and exports.

A large number of studies in the trade literature have focused on the influence of market factors on international trade flows. For exports, these factors include overseas demand for US products, exchange rates, an increased marketing effort by US manufacturers for foreign market opportunities, and a reduction in tariff rates on US exports that have been associated with free trade negotiations. The effects of exchange rates and aggregate economic output (which we also refer to as purchasing power in this study) on the balance of trade has been investigated at both national (e.g., Kim and Roubini 2000, Boyd et al. 2001) and industry levels (e.g., Cheng et al. 2013). In forest products, exchange rates have been used in studies of the trade in specific commodities (e.g., Alavalapati et al. 1997, Bolkesjø and Buongiorno 2006). Hänninen (1999) and Sun and Zhang (2003) examined the effect of exchange rate volatility on US forest products exports. However, no study has focused in particular on explaining the aggregate forest products trade balance.

Cyclical economic factors and trade policies are among forces potentially having large effects on trade, primarily through their influence on domestic forest products demand. As Figure 1 shows, the US trade balance (value of net exports) in forest products increases whenever the United States is in recession. This was especially evident in 1980–1981, 1991–1992, and 2007–2009, suggesting that a contraction in domestic demand during recessions works to make the forest products trade balance less negative or more positive. Yet, the existence of a trade surplus in forest products

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between 2009 and 2014, after the United States had pulled out of its most recent recession, suggests that other factors may be at work in more recent years. Unlike the previous recessions, when domestic supply typically contracted and expanded along with domestic demand, domestic forest products prices demonstrated an unusually slow recovery after the most recent recession (2007–2009, which in annual terms was only 2007 and 2008) (Figure 2). Research has shown that when domestic US producers face prolonged slumps in demand for their products, these producers may devote greater effort to expanding overseas markets (e.g., Zhang 2012).

In terms of policy shifts, trade measures affecting imports may also affect net exports. In particular, Prestemon (2015) showed that the implementation of an amended Lacey Act (LAA) in 2008 (amended in the Food, Conservation, and Energy Act of 2008, P.L. 110–234, 122 Stat. 923) may have slowed US imports of certain forest products from some countries. The LAA includes for the first time any tree species illegally obtained in the country of origin. US imports of any product containing illegally obtained tree materials are specifically banned, and importers are required to file an import declaration form attesting to the legal provenance of the declared tree species. It is plausible that the extra reporting requirements of the LAA have had broader effects on imports, even beyond the few products with documented effects measured by Prestemon (2015).

All of the above factors—purchasing power, exchange rates, economic recessions, expanded export marketing, and the LAA—are considered in this new analysis. Our results show that each of these hypothesized factors can help explain dynamics in the value of aggregate net forest products exports. The next section presents our theoretical framework, followed by empirical methodology, data, and empirical results. The final section draws some conclusions.

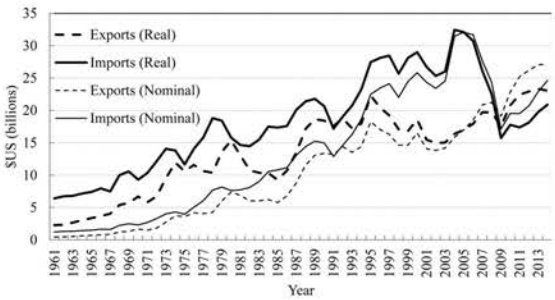

Figure 1. Nominal and real (2005 = 100) values of US forest products exports and imports: 1961–2014. (Source: FAO 2015.)

Theoretical Framework

This article adopts a two-region nonspatial partial equilibrium model between the United States and the rest of the world (ROW). International and domestic forest products are often substitutes, and trade balances change because of shifts in market conditions and trade policies. A depreciation in the US dollar raises the price of foreign forest products in US markets and lowers the foreign currency price of US forest products, encouraging US exports. Studies on different commodities have shown a negative effect of real exchange rates on forest products export quantities (Sun and Zhang 2003, Bolkesjø and Buongiorno 2006), whereas its impacts on forest products imports, especially the dynamic adjustment after a depreciation shock, remain ambiguous. Import spending of the United States is assumed to depend on domestic income, whereas foreign demand for US forest products is hypothesized to be influenced by aggregate economic output in the ROW, and the US dollar exchange rate. As US wood products demand has been shown to be linked most directly to housing starts, which are positively correlated with changes in economic output (gross domestic product [GDP]) in the United States, and as paper demand is also connected to changes in economic output (e.g., Buongiorno 2015), we use changes in GDP to explain changes in our modeled dependent variables.

A recession is defined as negative GDP growth in two consecutive quarters. The United States had seven recessions in our study period (beginning in 1961, 1970, 1974, 1981, 1990, 2001, and 2008). As Figure 1 shows, export revenue and import spending always shift in the first year of a recession and 1 year after the end of a recession. Two factors may have contributed to the trailing effects of recessions in the forest products sector. On the supply side, production arrangements negotiated by individual firms are usually planned ahead and therefore take time to adjust to economic fluctuations, including economic recovery. Furthermore, forest products manufacturing facilities with less production flexibility tend to have a higher probability of closing during recessions (Keegan et al. 2011, Pinkerton and Bennet 2013), cementing some of the recession-induced production contraction that extends well beyond the

Table 1. Top five forest products importers and exporters in the world: 2006–2014.

Country	2006	2007	2008	2009	2010	2011	2012	2013	2014
	(US $ billion, nominal value)								
Value of exports									
Canada	28.2	27.8	24.0	17.1	21.3	22.7	21.7	24.1	24.3
Finland	14.3	15.9	15.2	11.1	13.2	14.4	13.1	13.9	12.8
Germany	18.2	23.8	24.2	18.7	20.8	23.0	20.4	20.4	20.3
Sweden	14.6	16.6	17.2	14.1	15.5	17.3	15.2	16.0	15.0
United States	18.5	20.9	21.3	19.1[a]	22.9[a]	25.2[a]	26.2[a]	26.5[a]	27.1[a]
World	203.4	231.7	237.1	188.1	222.6	246.9	232.1	248.4	249.7
Value of imports									
People's Republic of China	16.6	20.5	20.9	20.1	27.6	36.9	35.2	38.7	47.0
Germany	16.0	20.8	21.5	15.8	19.3	21.6	19.1	19.3	19.0
Japan	12.8	12.3	12.4	9.9	11.9	14.1	13.4	13.4	12.4
United Kingdom	11.3	13.6	11.8	9.1	10.6	10.9	10.1	10.5	11.8
United States	31.7[a]	27.7[a]	24.3[a]	17.1	19.5	19.4	20.5	22.9	24.6
World	208.5	238.8	242.8	191.9	231.5	261.3	242.4	255.2	261.8

Source: FAO (2015).
[a] The United States is the largest exporter or importer of the world in that particular year.

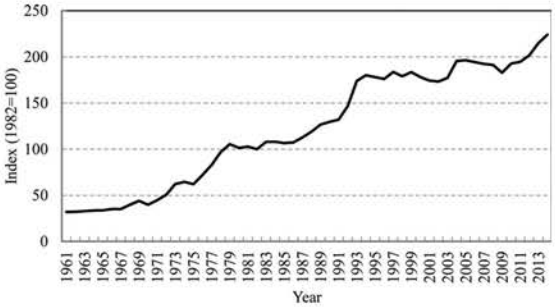

Figure 2. US lumber and wood products producer price index: 1961–2014. [Source: US Bureau of Labor Statistics 2015.]

resumption of aggregate economic growth. With respect to demand, as well, recessions have lingering negative consumption effects (e.g., Blanchard 1993), which last several quarters after resumption of aggregate economic growth.

What is interesting is that the improvement in trade balance has persisted since the resumption of aggregate economic growth in late 2009, a degree of persistence not observed in other recessions in the past half century. Recent research sheds light on the effectiveness of supplier efforts that could be indicative of potential causes. First, Zhang (2012) finds evidence of an increased effort to sell its products in overseas markets by a US producer during and after the 2007–2008 recession. Second, Zhang et al. (2017) show that export strategies of producers had direct effects on the production and capacity utilization in small- and medium-sized softwood sawmills during and after the housing crisis in the southern United States.

Our hypothesis is that a principal driving factor in the reduction of domestic US demand for forest products during the most recent recession was the contraction of domestic residential construction, the primary user of wood products (Wear et al. 2016). The housing sector contraction was unprecedented compared to experience since World War II. For example, total US housing starts fell from 2.1 million units in 2006, at the height of the most recent bubble in the construction sector (Shiller 2015), to about 600,000 units in 2008, a 70% decline from peak to trough. In 2014, US housing starts rose to 1.0 million units, still below a historical (1959–2006) average of 1.5 million units. Using the US lumber and wood products producer price index (PPI) as a measure of industry health, the slowdown in the forest products sector in the US coincided with most economic recessions, except the most recent recession, in which this PPI did not recover to its 2006 level until 2011 (Figure 2). So to account for the potential export efforts made by domestic producers in the period of forest industry slow-down, we consider using a dummy variable for the period of 2007 to 2010.

In many trade balance studies (e.g., Haynes and Stone 1982, Boyd et al. 2001, Cheng et al. 2013), the ratio of export revenue (hereafter denoted as X) to import spending (M) is used as the dependent variable. Similarly, we define the trade balance in forest products (B) as the ratio of export revenue X to import spending M. With lower-case letters indicating logarithms, $b = (x - m)$, following Goldstein and Khan (1985), US export revenue and import spending in aggregate forest products can be parsimoniously specified as a function of income, exchange rates, and a set of transitory shock variables:

$$x = a_0 + a_1 y^* + a_2 r + \sum f_i D_i + \varepsilon \quad (1)$$

$$m = b_0 + b_1 y + b_2 r + \sum g_i D_i + \sigma \quad (2)$$

where y and y^* are logarithms of real (inflation-adjusted) home and foreign (ROW) GDP; r is the logarithm of the real exchange rate; the D_i's are dummy variables representing the implementation of the LAA whose definition will be provided later, US recessions (with recessions = 1 for the years 1961–1962, 1970–1971, 1974–1975, 1981–1982, 1990–1991, 2001–2002, and 2007–2008 and 0 otherwise), and an index of domestic industry efforts to expand export marketing (= 1 for the years 2007, 2008, 2009, and 2010, with 0 otherwise); and ε and σ are residuals. Note that time subscripts are omitted but are implied in Equations 1 and 2, and the following expression of the trade balance (Balance):

$$\text{Balance} = (a_0 - b_0) + a_1 y^* - b_1 y + (a_2 - b_2) r + \sum (f_i - g_i) D_i + (\varepsilon - \sigma) \quad (3)$$

Estimating the trade balance in Equation 3 directly would hide the respective effects of economic and policy shocks on the exports or imports of US forest products trade. The dynamic adjustment process can be captured by employing the export revenue and import spending models separately, in addition to estimating the trade balance model. We expect that net exports in forest products increase as the relative purchasing power between ROW and the US increases, as the US dollar depreciates against other major currencies, when the United States is in recession, when the forest industry expands its marketing efforts, and as trade policies are implemented that are designed to discourage certain categories of forest products imports (the LAA to be specific).

VAR Model and Data

Given that we have time series data that possess an autoregressive structure, it is natural to assume that statistical estimation of Equations 1–3 requires the estimation of nuisance parameters, associated with autoregression, along with the structural parameters to achieve statistically consistent estimates. Therefore, Equations 1–3 are adapted to a vector autoregressive (VAR) framework, with deterministic time trends and exogenous variables:

$$w_t = A d_t + B(L) w_{t-1} + B_0 z_t + e_t \quad (4)$$

where $A = [\alpha, \alpha_0]$ and B_0 are matrix of coefficients to be estimated, $B(L)$ is a matrix polynomial in the lag operator L, and e_t is the vector of error term and serially uncorrelated. Vector d_t contains the constant and time variable t, which is $d_t = [1, t]^{-1}$. w_t is a 3×1 data vector with variables including the real exchange rate, the real dollar export revenue, and the ROW purchasing power (real aggregate output in US dollars) in the export model as specified in Equation 1, a 3×1 data vector with variables including the real dollar exchange rate, the real dollar import spending, and the US purchasing power (real dollar GDP) in the import model as specified in Equation 2, and a 4×1 data vector with variables including the real exchange rate, the real dollar trade balance, and the US and ROW purchasing powers as specified in Equation 3. All variables are transformed by the natural logarithm. z_t is a vector of dummy variables. In the export model, this vector includes dummies capturing US economic recessions and enhanced forest products industry marketing efforts.

Table 2. Summary statistics of variables in empirical model (before log-transformed): 1961–2014.

Variable	Observed	Unit	Mean	SD	Minimum	Maximum
Real exchange rate	54	Index (1973 = 100)	96.46	8.30	82.67	122.73
Trade balance	54	%	0.73	0.23	0.35	1.29
Export revenue	54	Billion $ (2005 dollars)	13.52	6.22	2.27	23.32
Import spending	54	Billion $ (2005 dollars)	18.23	7.23	6.40	32.46
GDP_US	54	Billion $ (2005 dollars)	8,219	3,694	2,926	14,797
GDP_ROW	54	Billion $ (2005 dollars)	22,126	10,556	6,729	43,258

In the import model, it includes the dummy variable for the implementation of the LAA and economic recessions. In the trade balance model, the vector includes all of these dummy variables.

In all three models (Equations 1–3), r_t is placed first, assuming that the real exchange rate is not contemporaneously influenced by other variables. The trade variables (x_t, m_t, b_t) are ordered second in each model, before income, assuming that forest products trade decisions are made in advance, but they are expected to respond to a US dollar weakening (i.e., an exchange rate depreciation shock) within the time span contained in a single temporal observation (i.e., within the year).

We have 54 years of data from 1961 to 2014. Data for US export revenue and import spending in terms of the dollar value of total forest products are obtained from the Food and Agriculture Organization of the United Nations (FAO) (FAO 2015). Forest products include wood products and paper products. The nominal export revenue and import spending values are converted into real values in the 2005 base year using the US GDP deflator. The ROW effective purchasing power is measured by the real dollar world GDP minus the GDP of the United States. Our GDP data are from the World Bank (World Bank 2015) in constant 2005 US dollars. Real exchange rate data are obtained from the Federal Reserve Board of St. Louis (2015), which has produced the BROAD (broad real effective exchange rate) index since 1973.

The BROAD index is a weighted average of foreign exchange values of US dollars against the currencies of a large group of major US trading partners. The real version of the BROAD index removes inflation by replacing the nominal bilateral rates with their real counterparts using the US consumer price index. To accommodate the change in exchange rate regimes from a fixed regime before 1973 to a floating regime during 1973 and thereafter, we assume that the pre-1973 exchange rate index values equal the 1973 value.

Table 2 presents summary statistics for variables used in the empirical model before logarithm transformation. The empirical estimation of Equation 4 starts with a test for stationarity of each variable in the model. We test the unit root properties using the Dickey-Fuller generalized least-squares (DF-GLS) test, considering its greater statistical power in small samples (Elliott et al. 1996). The number of lags in the DF-GLS test is selected according to the minimum of the Schwartz information criterion. Table 3 presents the test results. As we failed to reject the null hypothesis of unit root with all of the level data except for the log value of real exchange rate, we conclude that most of the time series are nonstationary. However, the first differences of all of the level variables are stationary.

Next, we estimated cointegration relations for the export, import, and trade balance models, respectively. Using Augmented Engle-Granger and Johansen tests, we cannot reject the null hypothesis that the variables are not cointegrated at the 5% level for each of the three models (Table 4). If the variables are cointegrated, an error correction term should be added into Equation 4 and the model

Table 3. Results of the unit root tests of individual time series.

	DF-GLS test			
	Levels (log)		First-differenced	
Variable	Lags	DF-GLS	Lags	DF-GLS
Real exchange rate	1	−3.01[a]	1	−3.77[b]
Export revenue	1	−1.26	1	−5.47[b]
Import spending	1	−1.61	2	−5.09[b]
Trade balance	1	−2.49	1	−4.85[b]
GDP_US	1	−1.19	1	−4.53[b]
GDP_ROW	1	−0.78	1	−4.62[b]

Number of lags is chosen based on the minimum Schwartz information criterion.
[a] $P < 0.05$.
[b] $P < 0.01$.

becomes the error correction model, which has been widely used in the literature, including use in models of forest products (e.g., Alavalapati et al. 1997, Boyd et al. 2001). When cointegration tests fail to identify statistically significant cointegrating relations among model variables, valid relationships can be established among the set of $I(d)$ variables by estimating a vector autoregressive model in first differences.

Therefore, we estimate Equation 4 using first differenced variables, which is

$$\Delta w_t = \alpha_0 + B(L)\Delta w_{t-1} + B_0\Delta z_t + Cu_t \qquad (5)$$

where u_t is a vector of normalized underlying structural shocks, that is, $Eu_tu_t' = I$, where I is the identity matrix, C is a matrix that describes the contemporaneous structural relationships among the endogenous variables Δw_t, and other variables and parameters are defined the same as in Equation 4. Assuming that the system is invertible, we can write Equation 5 as an infinite order moving average representation. $(I - B(L))^{-1}C$ and $(I - B(L))^{-1}B_0$ are the matrix of polynomials providing impulse-response and multiplier analysis functions, respectively (Lütkepohl 2005, p. 51–63, 406–408). We define the dynamic elasticity of a variable i on the other variable j at time point t as

$$\eta_j^i(t) = \frac{\phi_j^i(t)}{\phi_j^j(t)} \qquad (6)$$

where $\phi(\cdot)$ measures the cumulative orthogonalized responses of differenced variables Δw_t from the initial steady state. When $t = 0$, $\eta^i(0)$ reports the short-run elasticity contemporaneously as a shock in variable j occurs, and the long-term elasticity is calculated as the cumulative shock measured 10 years ahead. Note that the variable i can be export revenue, import spending, or trade balance and j can be the exchange rate or GDP in this study.

Because our dependent variables are first-differenced, we have defined the dummy variable for the LAA in two ways. One is that the variable takes the value as "1" for 2009 and "0" otherwise. In this

Table 4. Cointegration tests.

Hypothesis		Johansen cointegration rank tests: Trace statistic		Maximum-eigenvalue statistic		Augmented Engle-Granger' test	
H_0	H_1	Statistic	5% critical value	Statistic	5% critical value	Statistic	5% critical value
Export model							
$n = 0$	$n >= 0$	28.51	29.68	17.47	20.97	−2.93	−4.69
$n = 1$	$n >= 1$	11.04	15.41	10.77	14.07		
$n = 2$	$n >= 2$	0.27	3.76	0.27	3.76		
Import model							
$n = 0$	$n >= 0$	22.40	29.68	14.14	20.97	−3.55	−4.69
$n = 1$	$n >= 1$	8.26	15.41	5.05	14.07		
$n = 2$	$n >= 2$	3.21	3.76	3.21	3.76		
Trade balance model							
$n = 0$	$n >= 0$	54.73	47.21	23.89	27.07	−4.00	−5.36
$n = 1$	$n >= 1$	30.85	29.68	19.50	20.97		
$n = 2$	$n >= 2$	11.35	15.41	10.52	14.07		
$n = 3$	$n >= 3$	0.82	3.76	0.82	3.76		

Table 5. Estimation results of VAR models (with level effects of the LAA).

	ln(exports): (1)		ln(imports) (2)		ln(imports) (3)		ln(trade balance): (4)	
Variable	Coefficient	SE	Coefficient	SE	Coefficient	SE	Coefficient	SE
$\ln(ER)_{t-1}$	−0.927[b]	0.420	0.030	0.327	0.014	0.324	−0.767[a]	0.460
$\ln(exports)_{t-1}$	−0.122	0.171						
$\ln(imports)_{t-1}$			0.023	0.164	0.067	0.165		
$\ln(trade\ balance)_{t-1}$							0.037	0.169
$\ln(GDP_{row})_{t-1}$	2.282[b]	1.137					2.179	1.608
$\ln(GDP_{US})_{t-1}$			−0.811	0.914	8.935	6.859	6.799	10.026
$\ln(GDP_{US})^2_{t-1}$					−0.582	0.406	−0.348	0.572
Recession	−0.083	0.050	−0.144[c]	0.042	−0.141[c]	0.041	0.032	0.062
$Recession_{t-1}$	−0.170[c]	0.047	−0.138[c]	0.048	−0.142[c]	0.048	−0.015	0.065
F_Industry	0.040	0.058					0.168[b]	0.080
LAA			−0.303[c]	0.106	−0.312[c]	0.105	0.104	0.155
Trend	−0.008	0.040	0.085[c]	0.031	0.098[c]	0.032	−0.096[b]	0.049
R^2	0.386		0.436		0.461		0.368	

Imports, exports, and the trade balance are in real (2005) dollars; ER and F_industry are abbreviations for the real exchange rate and forest industry slowdown (which enhanced forest industry export marketing), respectively.
[a] $P < 0.10$.
[b] $P < 0.05$.
[c] $P < 0.01$.

case, the LAA is hypothesized to have only caused a change in the intercept but not the slope of the linear trend. In other words, the effect of LAA is only in the levels of forest products imports and trade balance. Alternatively, the LAA may influence imports and trade balance gradually after its implementation. Thus, we also consider an alternative definition for the variable to take the value of "1" after 2008 and "0" otherwise. We report the results in both ways in Tables 5 and 6, respectively.

The Akaike information criterion is used to select the number of lags as 1 in the exports, imports, and trade balance VAR models. All eigenvalues of the state-space representation companion matrix are strictly less than 1, indicating that the models are jointly stationary with detrended first-difference estimation. The Lagrange multiplier (LM) test is used to check for residual autocorrelation in the VAR models (Johansen 1995, p. 21–22). The null hypothesis is that there is no autocorrelation in the residuals for the number of orders tested. We perform the LM test at lags 1–5 and find no residual autocorrelation in either the export, import, or trade balance models.

Results

Tables 5 and 6 report the estimation results of the first-difference VAR models, with different specifications for the LAA dummy variable. The R^2 values for the import and trade balance models were higher when they were evaluated with level effects of the LAA (Table 5) than with trend effects (Table 6). Moreover, the import model with level effects provides a more straightforward interpretation in terms of the relationship between the LAA and import spending.

Therefore, we confine most of the discussion of our results to the level effects assumption of the LAA. The real exchange rate had a negative effect on export revenues, significantly different from 0 at the 5% level. Therefore, and as expected, US dollar depreciation had a positive and statistically significant effect on net exports (the trade balance) of forest products, whereas depreciation had an insignificant effect on import spending. Thus, the effect of dollar depreciation on trade balance operated mainly through exports.

ROW GDP had a positive effect on US forest products export revenues. Because these models were estimated in natural logarithms, coefficients represent elasticities. Given the magnitude of the ROW

Table 6. Estimation results of VAR models (with trend effects of the LAA).

Variable	ln(imports) (2) Coefficient	SE	ln(imports) (3) Coefficient	SE	ln(trade balance): (4) Coefficient	SE
$\ln(ER)_{t-1}$	0.161	0.343	0.152	0.342	−0.818[a]	0.455
$\ln(\text{imports})_{t-1}$	0.069	0.174	0.106	0.176		
$\ln(\text{trade balance})_{t-1}$					0.022	0.169
$\ln(GDP_{row})_{t-1}$					2.138	1.614
$\ln(GDP_{US})_{t-1}$	−1.267	1.023	6.990	7.357	7.664	10.044
$\ln(GDP_{US})^2_{t-1}$			−0.492	0.434	−0.390	0.573
Recession	−0.154[c]	0.045	−0.151[c]	0.045	0.036	0.063
Recession_{t-1}	−0.193[c]	0.048	−0.197[c]	0.049	0.004	0.060
F_Industry					0.189[c]	0.073
LAA	−0.072	0.048	−0.070	0.048	0.019	0.060
Trend	0.108[a]	0.037	0.119	0.038	−0.102[b]	0.052
R^2	0.364		0.382		0.363	

[a] $P < 0.10$.
[b] $P < 0.05$.
[c] $P < 0.01$.

GDP coefficient (2.28), it is clear that export revenues responded elastically to foreign purchasing power changes and that these changes were more elastic than those associated with exchange rate changes, whose effects were inelastic. The results of regression (2) in Table 5, modeling import spending, indicate that import spending declined as the purchasing power in the United States increased, although the measured elasticity, −0.81, was statistically significant. Kayo et al. (2015) found an inverted-U relationship between per capita GDP and per capita wood consumption, implying that consumption should decline as economic development progresses beyond some saturation consumption level. Results for imports using regression (3) support this inverse-U hypothesis, but coefficients on the level and the squared terms were statistically insignificant at the 5% level. In the following, we limit our discussion on import spending to the results of regression (3).

The economic recession had significant negative effects on US forest products import spending, with current year and lagged recession indicators both signed negatively and statistically significant at 1%. The decline in import spending works to make the US balance of trade in forest products more positive, although the coefficient of the recession variable in the trade balance model, regression (4), was statistically insignificant at 5%.

Forest industry marketing efforts had a statistically significant and positive effect on net exports, as measured by the trade balance, supporting a contention that domestic producers increased their sales efforts in overseas markets during the most recent economic recession. However, this positive effect of sales actions by domestic producers was not large enough to overcome the negative effects of the economic recession on sector level export revenues, as revealed by the estimation results of the export model. As expected, the LAA had a statistically significant and negative effect on US import spending in forest products, which acted to increase the US trade balance in forest products. However, the positive effects of the LAA were statistically insignificant in the trade balance model. This last result could have been obtained because only a small portion of US imports derived from countries with suspected high rates of illegal wood production (Li et al. 2008).

The above estimated coefficients of the VAR models helped explain why the United States' trade position in forest products shifted

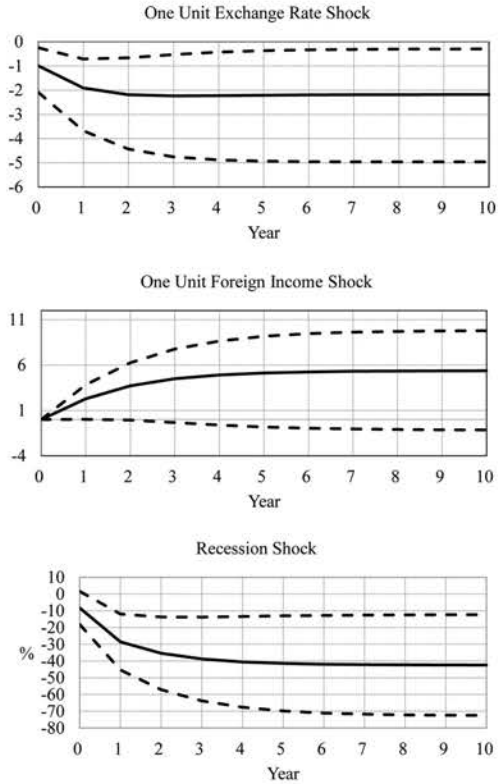

Figure 3. Impulse response and dynamic-multiplier estimation: export model. Dashed lines are 95% confidence bands. The graphs in Figures 3, 4, and 5 with continuous variables are unitless because the y-axis is normalized by a 1-unit change in the independent variable.

so substantially. The impulse response and dynamic multiplier analysis provide a more graphical understanding of how the forest products market moves toward equilibrium after various market shocks. Figures 3–5 report the dynamic responses of export revenues, import spending, and the trade balance, respectively, to a 1% unexpected increase in other variables. The impulse response functions are only generated for relationships found to be statistically significant. The long-run responses in these figures are shown for 10 years ahead, which is long enough for shocks to largely disappear, as is demonstrated by the flattening of the curves over time.

Two findings are noteworthy. First, the exchange rate responses to its own shock are similar in the export (Figure 3) and trade balance (Figure 5) models. After the initial 1% shock, the exchange rate increases slightly for about 5 years, reaching an equilibrium at about 1.8 to 2.2%; as noted in the equation results discussion, its effect on the trade balance operates mainly through exports. Second, when there is an unexpected economic recession shock, import spending (Figure 4) decreases quickly and substantially in the first year and reaches an equilibrium with a slight increase in the second year, whereas export revenues (Figure 3) respond with a gradual but permanent decline through the succeeding 10 years. However, export revenue may drop more than two times as much as the import

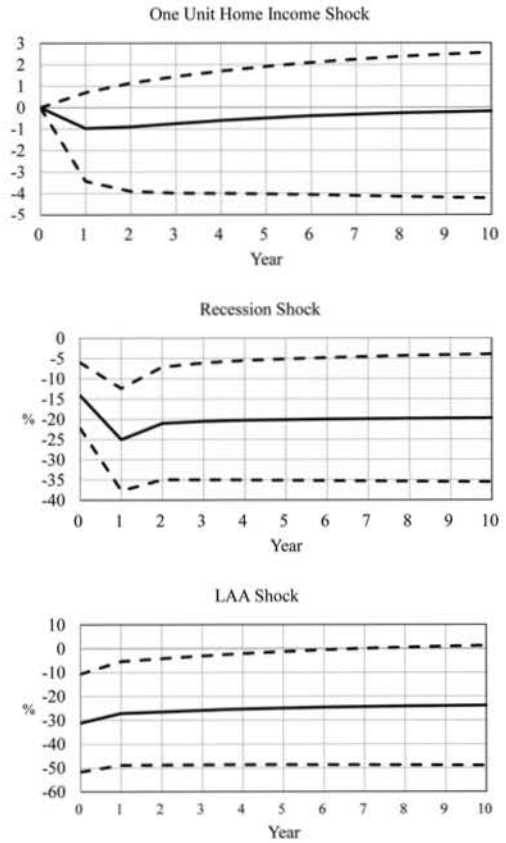

Figure 4. Impulse response and dynamic-multiplier estimation: import model. Dashed lines are 95% confidence bands.

spending decrease 5 years after the recession shock. We reiterate, however, that the recession effect on the trade balance was statistically insignificant in regression (4) (Table 5).

Export Revenue Adjustment

In the first panel of the impulse responses shown in Figure 3, we see that a contemporaneous 1% real exchange rate shock decreases forest products export revenues by 1.0%. This negative effect continuously extends and converges to an equilibrium, with a −2.2% long-run effect. US dollar depreciation from 110.3 in 2002 to 86.3 in 2011 therefore explains at least part of the expansion in US forest products exports and increase in net exports over the time span. In the response functions shown in Figure 3, export revenue increases and reaches an equilibrium with a value of 5.3% after 7 years, when there is 1% foreign purchasing power shock. About 84.5% of the total increase in export revenues occurs in the first 3 years.

Import Spending Adjustment

As in the export model, US GDP is the third variable in the import spending model, and it is assumed, through our specifications of regressions (2) and (3) to not have a contemporaneous effect on import spending. When there is a 1% US GDP shock, US

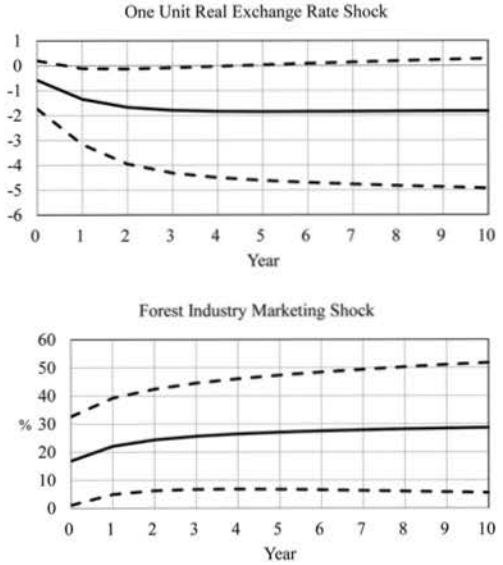

Figure 5. Impulse response and dynamic-multiplier estimation: trade balance model. Dashed lines are 95% confidence bands.

import spending on forest products decreases substantially in the first year and reaches the lowest point estimate of −1.0% in that same year. Subsequently, import spending rises moderately over the ensuing 7 years, reaching a long-run point estimate of an equilibrium change of −0.2%.

The response functions measuring the effects of a recession in Figures 3 and 4 show how export revenues and import spending, respectively, respond to the advent of a recession, and they are measured in fractions of the total, i.e., a 0.10 change in the dependent variable reflects a 10% change in that variable. When there is an exogenous economic recession shock, import spending decreases substantially in the first year, by 25%, followed by a slight increase, and reaches a long- run equilibrium of −20%. The initial 31% decrease in import spending influenced by the implementation of the LAA also converges to −24% in the long run.

Trade Balance Adjustment

As shown in the last two columns in Table 5, the real exchange rate had a negative effect on the trade balance at the 10% significance level. As modeled in the impulse response (Figure 5), the trade balance increases and reaches an equilibrium at 1.8% after 3 years, when there is a 1% exchange rate depreciation shock. Moreover, under a depreciation shock, the movements of the trade balance in Figure 5 resemble movements of export revenue in Figure 3, which again indicates that the real exchange rate influences the trade balance through its effect on exports.

When the forest industry experiences a slow-down, US domestic forest products producers may increase their marketing efforts in overseas markets, which increases the trade balance. We found that this effect was significant in the trade balance model, regression (4) (Table 5), and this effect is documented in the impulse response displayed in Figure 5, demonstrating a significant 17% increase after 1 year. The trade balance response amplifies gradually in the long run, reaching 28% after 7 years.

Table 7. Dynamic elasticity estimates.

No. of years ahead	Export		Import: GDP_US	Trade balance: exchange rate
	Exchange rate	GDP_ROW		
0	−0.991			−0.580
1	−1.361	1.428	−0.855	−0.944
2	−1.424	1.922	−0.744	−1.048
3	−1.422	2.138	−0.595	−1.074
4	−1.409	2.244	−0.467	−1.081
5	−1.398	2.298	−0.368	−1.080
6	−1.390	2.327	−0.292	−1.078
7	−1.386	2.341	−0.234	−1.075
8	−1.384	2.349	−0.189	−1.071
9	−1.382	2.353	−0.154	−1.068
10	−1.382	2.355	−0.126	−1.066

Long-Term Elasticities

Estimates of long-term elasticities are reported in Table 7. An elasticity greater than 1 indicates an overcorrection of the US forest products trade-in response to the other endogenous variables, the real exchange rate, and purchasing power, whereas an elasticity smaller than 1 represents an undercorrection.

The −0.13 income elasticity of import spending implies that a 1% increase in income induces US consumers to spend 0.13% less on imported forest products in the long run. This result implies that imported forest products are inferior goods for US consumers. On the other hand, a 1% increase in foreign purchasing power has a positive effect of 2.36% on the US export revenues of forest products in the long run, indicating that export revenue overcorrects in response to foreign income shocks in the long run.

The long-run elasticity of the trade balance with respect to a real exchange rate change implies a near doubling from its short-run value: from an inelastic −0.58 level to an approximately unitary elasticity of −1.07, achieved 8 years after a shock. Compared to trade balance, the initial elasticity of export revenue on depreciation shock is elastic, with a value of −1.00. The effect of US dollar depreciation is long lasting and expands rapidly in the first 3 years.

Conclusions and Discussion

In this article, we sought to identify factors contributing to the recent changes in the net trade position of the United States, shown to have shifted from status as a net importer to a net exporter in the aggregate value of all traded forest products, evident since 2009. We used vector autoregressive models to model export revenues and import spending separately, to capture the dynamic adjustment processes and reveal the influencing channels of market shocks. Besides the exchange rate and purchasing powers, we evaluated whether there is evidence of structural change in the US forest products sector attributable to economic recessions, enhanced forest products export marketing efforts, and the implementation of the 2008 Lacey Act Amendment. Our statistical results show that all of these factors contributed to the change in the aggregate US forest products trade balance.

Furthermore, we found that export revenue and import spending responded differently to the exogenous variables included in our models.

As expected, we found that the US forest trade balance increases (net exports increase) in the short run due to the demand contraction associated with economic recessions and to the enhanced export marketing efforts by industry. Expanded marketing is coincidentally aided by positive and elastic responses of US exports to foreign income changes. We also find that trade policy can significantly affect the net trade position of the United States: since 2009, the LAA has provided a boost to net exports by reducing forest products imports.

In addition, shifts in exchange rates and purchasing power, as measured by the value of total economic output, were identified as having persistent, significant influences on the trade balance in US forest products. Thus, the depreciation of the US dollar since 2002 and the high growth in foreign purchasing power by our trading partners in the last two decades were found to be important factors explaining recent increases in exports and net exports. Domestic and foreign consumers are sensitive to income changes, and forest products tend to be inferior goods in the United States.

In our study, variables explaining changes in the trade balance exhibited similar paths of adjustment after external shocks to the real exchange rate and industry export marketing efforts. The effects of real exchange rate shifts were amplified recursively and gradually over time. The effects of enhanced export marketing efforts were amplified and long lasting.

Although the models estimated for this study were based on historical data and produced statistically significant findings about how the forest products sector responds to historical economic and policy variables, we are cautious about offering predictions of the future. We know that US economic recessions are exceptional short-term shocks and that the impact of the LAA is limited in the long run, and we might surmise that enhanced export marketing could fade as sector recovery advances. That said, based on our model estimates, the answer to this question depends largely on the future of the domestic US economy, in particular, economic growth, which has a significant impact on the residential housing sector and which has historically demonstrated strong dependence on wood product imports to satisfy demand, and the exchange rate and the trajectory of global economic growth. Weak domestic demand, coupled with strong economic growth in overseas markets for US exports, for example, would provide support for a continued positive balance of trade in forest products. On the other hand, a stronger dollar and vigorous domestic economic activity would push net exports in the opposite direction in the coming years.

Literature Cited

ALAVALAPATI, J., W.L. ADAMOWICZ, AND M. LUCKERT. 1997. A cointegration analysis of Canadian wood pulp prices. *Am. J. Agri. Econ.* 79(3):975–986.

BLANCHARD, O. 1993. Consumption and the recession of 1990–1991. *Am. Econ. Rev.* 83(2):270–274.

BOLKESJØ, T.F., AND J. BUONGIORNO. 2006. Short-and long-run exchange rate effects on forest product trade: Evidence from panel data. *J. For. Econ.* 11(4):205–221.

BOYD, D., G.M. CAPORALE, AND R. SMITH. 2001. Real exchange rate effects on the balance of trade: Cointegration and the Marshall-Lerner condition. *Int. J. Finan. Econ.* 6:187–200.

BUONGIORNO, J. 2015. Monetary union and forest products trade—The case of the euro. *J. For. Econ.* 21:238–249.

CHENG, K.M., H. KIM, AND H. THOMPSON. 2013. The real exchange rate and the balance of trade in US tourism. *Int. J. Finan. Econ.* 15:122–128.

ELLIOTT, G., T.J. ROTHENBERG, AND J.H. STOCK. 1996. Efficient tests for an autoregressive unit root. *Econometrica* 64:813–836.

FOOD AND AGRICULTURE ORGANIZATION OF THE UNITED NATIONS. 2015. *FAOSTAT.* Available online at faostat3.fao.org/download/F/FT/E; last accessed Sept. 25, 2015.

FEDERAL RESERVE BOARD OF ST. LOUIS. 2015. *FRED economic data*. Available online at research.stlouisfed.org/fred2/series/TWEXBPA#; last accessed Sept. 25, 2015.

GOLDSTEIN, M., AND M.S. KHAN. 1985. Income and price effects in foreign trade. P. 1041–1105 in *Handbook of international economics*, Jones, R.W., and P.B. Kennen (eds.). Elsevier, Amsterdam, The Netherlands.

HÄNNINEN, R. 1999. Exchange rate pass-through in Finnish sawnwood exports to the United Kingdom. P. 41–54 in *Modern time series analysis in forest products trade*, Abildtrup, J., F. Helles, P. Holen-Andersen, and B. J. Thorsen (eds.). Kluwer Academic Publishers, Boston, MA.

HAYNES, S., AND J. STONE. 1982. Impact on the terms of trade on the US trade balance: A reexamination. *Rev. Econ. Stat.* 64:702–286.

HOWARD, J.L., AND R.M. WESTBY. 2013. *US timber production, trade, consumption, and price statistics 1965–2011*. USDA For. Serv., Res. Pap. FPL-RP-676, Forest Products Laboratory. 99 p.

JOHANSEN, S. 1995. *Likelihood-based inference in cointegrated vector autoregressive models*. Oxford University Press, Oxford, UK. 280 p.

KAYO, C., H. OKA, S. HASHIMOTO, M. MIZUKAMI, AND S. TAKAGI. 2015. Socioeconomic development and wood consumption. *J. For. Res.* 20(3):309–320.

KEEGAN, C.E., C.B. SORENSON, T.A. MORGAN, S.W. HAYES, AND J.M. DANIELS. 2011. Impact of the great recession and housing collapse on the forest products industry in the western United States. *For. Prod. J.* 61(8):625–634.

KIM, S., AND N. ROUBINI. 2000. Exchange rate anomalies in the industrial countries: A solution with a structural VAR approach. *J. Monet. Econ.* 45(3):561–586.

LI, R., J. BUONGIORNO, J.A. TURNER, S. ZHU, AND J.P. PRESTEMON. 2008. Long-term effects of eliminating illegal logging on the world forest industries, trade, and inventory. *For. Policy Econ.* 10(7/8): 480–490.

LÜTKEPOHL, H. 2005. *New introduction to multiple time series analysis*. Springer, New York. 764 p.

PINKERTON, E.W., AND J. BENNER. 2013. Small sawmills persevere while the majors close: Evaluating resilience and desirable timber allocation in British Columbia, Canada. *Ecol. Soc.* 18(2):34.

PRESTEMON, J.P. 2015. Modeling the impacts of the Lacey Act Amendment of 2008 on US hardwood lumber and hardwood plywood imports. *For. Policy Econ.* 50:31–44.

SHILLER, R.J. 2015. *Irrational exuberance: Revised and expanded third edition*. Princeton University Press, Princeton, NJ. 392 p.

SUN, C., AND D. ZHANG. 2003. The effect of exchange rate volatility on US exports of forest products. *For. Sci.* 49(5):807–814.

US BUREAU OF LABOR STATISTICS. 2015. *PPI database*. Available online at www.bls.gov/ppi/data.htm; last accessed July 15, 2016.

US CENSUS BUREAU. 2016. *US trade in goods and services—Balance of payments (BOP) basis*. Available at www.census.gov/foreign-trade/statistics/historical/gands.txt; last accessed July 15, 2016.

WEAR, D.N., J.P. PRESTEMON, AND M.O. FOSTER. 2016. US forest products in the global economy. *J. For.* 114(4):483–493.

WORLD BANK. 2015. *GDP at market prices (constant 2005 US$)*. Available online at data.worldbank.org/indicator/NY.GDP.MKTP.KD; last accessed Sept. 25, 2015.

ZHANG, D. 2012. Exports propel McShan Lumber Company to new high. *Ala. For.* 56(4):8–9.

ZHANG, D., Y. LIN, AND D. SASATANI. 2017. Dealing with the housing crisis: A study on softwood sawmills in the south US. *For. Prod. J.* In press.