# Softwood Lumber Products in the United States: Substitutes, Complements, or Unrelated?

Rao V. Nagubadi, Daowei Zhang, Jeffrey P. Prestemon, and David N. Wear

**ABSTRACT.** This study addresses an important dimension concerning the softwood lumber trade dispute between United States and Canada—substitutability among imported and domestically produced species. We employ the restricted translog subcost function approach to study this issue based on the monthly data of US softwood products consumption and prices between Jan. 1989 and July 2001. The results show that the spruce-pine-fir lumber species group, mainly imported from Canada, is largely unrelated to domestically produced treated southern yellow pine, Douglas-fir, and other species groups, but is a substitute to untreated southern yellow pine and engineered wood products. Furthermore, untreated southern yellow pine is facing more severe competition from structural panels rather than from the imported Canadian spruce-pine-fir group. FOR. SCI. 50(4):416–426.

**Key Words:** Trade dispute, US-Canada, southern pine, spruce-pine-fir, engineered wood products, translog subcost function.

Among the trade conflicts between Canada and the United States, the softwood lumber dispute has been the most important in terms of trade volumes and values, complexity, procedure, politicization, and duration (Zhang 1997, Gagne 1999). Softwood lumber is one of the largest commodities produced by the forest industry in both countries. In 2001, Canada exported 43.75 million cubic meters of softwood lumber to the United States, accounting for 34% of total US softwood lumber consumption. This constituted 85% of all softwood lumber exports from Canada and 93% of all softwood lumber imports into the United States. With the expiration of the Softwood Lumber Agreement (SLA) that reigned for 5 years from 1996 to 2001, the softwood lumber trade confrontation between the United States and Canada has entered a new phase.

In Apr. 2001, some US lumber producers filed complaints to the US Department of Commerce (USDC), claiming that Canadian softwood lumber imports hurt them. A key argument used by these producers was that US and Canadian softwood lumber are substitutes. Their statistical evidence was that the price correlation between spruce-pine-fir (an aggregate product class consisting of *Picea* spp., *Pinus* spp., *Abies* spp.) (SPF, the main softwood lumber species group imported from Canada) and southern yellow pine (mainly, *Pinus echinata* Mill., *P. taeda* L., *P. elliotii* Engelm.) (SYP, the largest single species groups produced in the United States) was around 0.8 based on historical data (Ragosta et al. 2000). More sophisticated empirical analyses of lumber demand (e.g., Buongiorno et al. 1988, Lewandrowski et al. 1994) also lend credence to this argument. In a latest development, on May 2, 2002, the US International Trade Commission voted unanimously that the US lumber producers were threatened with injury from lumber imported from Canada, clearing the way for new duties. The duties, averaging 27.22% ad valorem, are large compared to

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duties on other imported countries and zero tariffs on most other forest products from Canada.

US consumer groups and the Canadian lumber industry, in contrast, claim that Canadian lumber imports and softwood lumber produced in the US are not substitutes and that Canadian imports meet US consumer demand and do not injure US lumber producers (ACAH 2002, NAHB 2002). The National Association of Home Builders (NAHB) argues that the different types of lumber for house framing are not interchangeable and that one wood product cannot be substituted for another without significantly harming US consumers by forcing them to spend more on a house. That is, because SPF from Canada is better suited for wall framing and SYP is best used for beams and joists, they may, in fact, even be complements. Hence, raising tariffs on imported SPF would adversely affect demand for both SYP and SPF.

Southern pine dominates outdoor wood construction applications such as decking and fencing and it is used extensively in large dimension (timber framing) applications. While SPF is the largest consumed lumber product in the United States, it is also the least domestically produced and largest imported lumber product (Figure 1). On the other hand, SYP is largely domestically produced. Canadian SPF is the preferred wood for wall framing due to its workability, strength, stability, and low density. Indeed, both species groups are used in the construction industry, often in the same building.

The purpose of this article is to look at the issue of substitutability and complementarity between various softwood lumber products in US consumer demand with empirical analysis based on economic theory. Insights generated from this study could help inform debates in the current US-Canada softwood lumber trade dispute and might have implications on the competitiveness of the US lumber industry and forest-based economic development in the different regions of the United States.

Earlier studies conclude that the exchange rate influences the share of Canadian lumber in the US lumber market (Adams et al. 1986) and that Canadian lumber imports do not affect US lumber prices (Buongiorno et al. 1988). Other studies (e.g., Wear and Lee 1993, Zhang 2001) address the welfare consequences of various trade restrictions on Canadian lumber. Studies examining species substitution focus on tropical and temperate sawlog imports in Japan (Vincent et al. 1991), tropical log imports from different world regions in Japan (Vincent et al. 1990), and domestic and imported industrial woods in the 36 most important wood-importing countries (Uusivuori and Kuuluvainen 2001). Hseu and Buongiorno (1993) find significant elasticity of demand for Canadian lumber imports with respect to US domestic lumber price, suggesting the possibility of substitution. However, Hseu and Buongiorno (1993) concentrate on substitution among softwood lumber species imported from Canada, not total US consumption, and their data were prior to 1989. Lewandrowski et al. (1994) examine the substitutability among imported lumber species and domestic lumber species in the United States. That study, also based on data from the 1970s and 1980s, does not distinguish between treated and untreated SYP and therefore does not address the period after the emergence of large volumes of treated SYP (treated SYP production increased 15-fold between 1977 and 1987, to a level where it essentially remains today). Neither study could have incorporated information related to higher prices for naturally durable western species such as redwood (*Sequoia sempervirons* [D. Don.] Endl.) (Olson et al. 1988, Berck and Bentley 1997) or the evolution in building technologies that involve greater use of structural panels. This study, in contrast, is based on later data and includes all important domestic and imported species groups as well as structural panels and other engineered wood products.

The rest of the article is organized as follows. In the next section, the theory on which our analysis is based and the empirical specification are described. In the third and fourth sections, data used in this analysis and empirical results are presented. The final section draws some conclusions and policy implications.

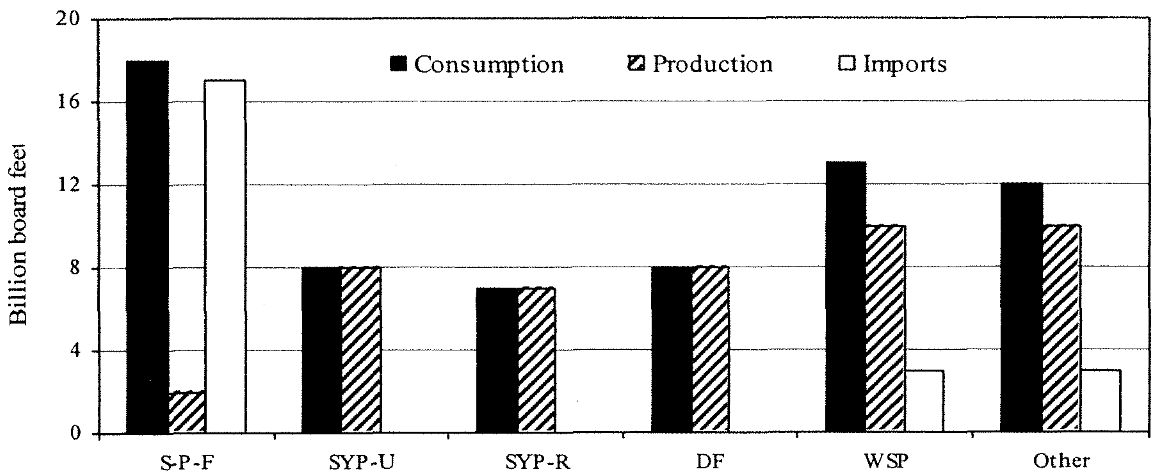


**Figure 1. Softwood products consumption, production, and imports in the United States: 2001.**

## Methods

To capture a full picture of the softwood products market, we include wood structural panels (WSP) that include softwood plywood, oriented strand board (OSB), and waferboard in our analysis. Following Fuss (1977) and Uusivuori and Kuuluvainen (2001), we adopt a two-stage approach in our analysis. First, the aggregate production function of softwood-utilizing industries (housing construction and remodeling and repair industry) has several major input categories, capital ($K$), labor ($L$), energy ($E$), softwood products ($S$), and other materials ($M$); each may consist of several components. Considering that the softwood-utilizing industries can choose among a number of softwood species or products, $S_i$, $i = 1, 2, \ldots, N$, and assuming a homothetic weakly separable production technology, the underlying production function can be written as

$$Y = f[S(S_1, S_2, \ldots, S_N), K, L, E, M] \quad (1)$$

where $Y$ denotes the gross output of the softwood-utilizing industries, $S$, the total consumption of softwood products, is an aggregate function for softwood products. The corresponding cost function will be

$$C = g[P^S(P^{S_1}, P^{S_2}, \ldots, P^{S_N}), P^K, P^L, P^E, P^M, Y] \quad (2)$$

where $C$ denotes the total cost of the softwood-utilizing industries and $P^S$, $P^K$, $P^L$, $P^E$, and $P^M$ are respective prices for inputs $S$, $K$, $L$, $E$, and $M$. Because in Equation 2, $P^{S_i}$, i = 1, 2, . . . , $N$, is the price per unit of softwood products $i$, it is also the cost per unit of softwood products to the softwood-utilizing industries.

Second, assuming weak separability, an unrestricted subcost function for the softwood product component of the production function can be written as

$$C^S = h(P^{S_1}, P^{S_2}, \ldots, P^{S_N}, Q) \quad (3)$$

where $C^S$ is the total cost of softwood product component, $P^{S_i}$, ($i = 1, 2, \ldots, N$) are prices for softwood products, and $Q$ is aggregate softwood products consumption by softwood-utilizing industries. This approach of subcost function permits us to study the structure of substitution between various softwood products independently of the other inputs.

The least restrictive approach in the empirical analysis is to assume a translog cost function. It does not require a priori restrictions on substitution possibilities. The translog function can be regarded as a quadratic approximation to the unspecified "true" cost function and is written as a Taylor series expansion to the second term of a twice-differentiable analytic cost function. Because a subcost function approach is used, this is termed a translog subcost function. After accounting for the effect of different time periods (explained below) and adding period dummy variables $T_2$ and $T_3$ to Equation 3, this function takes the form:

$$\begin{aligned}\ln C^S = {} & \alpha_0 + \alpha_{T_2}T_2 + \alpha_{T_3}T_3 + \alpha_Q \ln Q + \frac{1}{2}\alpha_{QQ}(\ln Q)^2 \\ & + \sum_i \alpha_i \ln P^{S_i} + \frac{1}{2}\sum_i \sum_j \beta_{ij} \ln P^{S_i} \ln P^{S_j} \\ & + \sum_i \beta_{iQ} \ln Q \ln P^{S_i} + \sum_i \beta_{iT_2} T_2 \ln P^{S_i} \\ & + \sum_i \beta_{iT_3} T_3 \ln P^{S_i} \end{aligned} \quad (4)$$

where $C^S$ is the total cost of softwood products in the softwood-utilizing industries; $P^{S_i}$ are softwood product prices, $i$ = 1–6 (1, SPF; 2, SYP-untreated; 3, SYP-treated; 4, Douglas-fir; 5, WSP; and 6, other species); $T_2$ is from Sept. 1994 to Mar. 1996 and Apr. to July 2001 (the free trade period), 0 otherwise; $T_3$ is 1 from Apr. 1996 to Mar. 2001 (the SLA period), 0 otherwise; $Q$ is the quantity of softwood products consumed by the softwood-utilizing industry; and $\alpha$ and $\beta$ are coefficients. Period 1 ($T_1$) is from Jan. 1989 to Aug. 1994, during which the Memorandum of Understanding (MOU), the interim duty, and the countervailing duty were in force. $T_1$ is omitted from Equation 4, and the effect of this period is captured by the intercept. These three periods are identified to capture the effect of various phases of US-Canada softwood lumber trade relationship on substitution and demand for softwood lumber.

According to Shephard's lemma, cost-minimizing behavior implies that the demand functions for the individual softwood lumber species, in terms of cost shares ($m^{S_i}$) in the softwood lumber aggregate cost, can be expressed as

$$\frac{\partial \ln C^S}{\partial \ln P^{S_i}} = m^{S_i} = \alpha_i + \sum_j \beta_{ij} \ln P^{S_j} + \beta_{iQ} \ln Q + \beta_{iT_2}T_2 + \beta_{i_3}T_3 \quad i = 1, 2, \ldots, N \quad (5)$$

When Equation 5 is estimated subject to constraints imposed by neoclassical production theory, the structure of substitution and price elasticities of demand for softwood products in the United States can be obtained given any set of relative prices and total softwood product consumption.

According to neoclassical production theory, linear homogeneity requires the following restrictions:

$$\sum_i \alpha_i = 1 \quad (6a)$$

$$\sum_j \beta_{ji} = \sum_i \beta_{ij} = 0 \quad (6b)$$

$$\beta_{ij} = \beta_{ji},\ i \neq j \quad (6c)$$

$$\sum_i \beta_{iQ} = \sum_i \beta_{iT_2} = \sum_i \beta_{iT_3} = 0 \quad i = 1, 2, \ldots, N. \quad (6d)$$

These restrictions ensure that the cost function is homogeneous of degree one in prices and that the Hessian matrix of the cost function is symmetric. Symmetry and linear homogeneity conditions ensure that the sum of factor shares in total cost adds up to unity.

The system of cost share in Equation 5 contains all the information needed to estimate the structure of substitution and price elasticities of demand. Allen partial elasticities of substitution (AES) can be calculated as (Binswanger 1974)[1]

$$\sigma_{ii}^{A} = \frac{\beta_{ii} + m_i^2 - m_i}{m_i^2} \quad i = 1, 2, \ldots, N \tag{7}$$

$$\sigma_{ij}^{A} = \frac{\beta_{ij} + m_i m_j}{m_i m_j} \quad i, j = 1, 2, \ldots, N; \; i \neq j \tag{8}$$

The elasticity of substitution measures the percent change in the input-use ratio for a percent change in input-price ratio. It represents the ease with which a production factor substitutes or complements for another in the production process. A positive sign indicates substitutability and a negative sign complementarity.

Own- and cross-price elasticities of demand can be calculated as follows

$$\eta_{ii} = m_i \sigma_{ii}^{A} = \frac{\beta_{ij} + m_i^2 - m_i}{m_i} \quad i = 1, 2, \ldots, N \tag{9}$$

$$\eta_{ij} = m_j \sigma_{ij}^{A} = \frac{\beta_{ij} + m_i m_j}{m_i} \quad i, j = 1, 2, \ldots, N; \; i \neq j. \tag{10}$$

The own- and cross-price elasticities of demand measure the percentage change in a factor use for a percent change in the own-price or the price of another good. Again, a positive sign indicates substitutability and a negative sign complementarity.

## Data

Data on total softwood products consumption in the United States were compiled based on an identity: consumption = production + imports – exports. Monthly data on lumber production were obtained from the American Forests and Paper Association (AF&PA). However, AF&PA does not give any species breakdown. The monthly shares of lumber production by species were estimated by instruments.[2] Import and export data for softwood lumber were taken from the US International Trade Commission's (USITC) Data Web (dataweb.usitc.gov). From 1989 onward, the United States has used the Harmonized Tariff Schedule (HTS) system of classification.[3] Data prior to 1989 were not considered due to changes in the classification system in 1988.

Initially, six lumber species groups, spruce-pine-fir (SPF), southern yellow pine (SYP), Douglas-fir, hem-fir, cedar, and an aggregate of other softwood species, were determined on the basis of available information from USDC classification and USITC codes descriptions (Table 1). Southern yellow pine production data were further divided into treated (SYP-R) and untreated (SYP-U) groups

**Table 1. Softwood lumber species groups identified by the US Department of Commerce and the US International Trade Commission.**

| Species group | USDC listed species | HTS listed species |
|---|---|---|
| SPF | Spruce & fir | SPF |
| | Lodgepole pine | Lodgepole pine |
| | Spruce | Sitka spruce |
| | | Other spruce |
| SYP | Southern pine | Southern yellow pine |
| Douglas-fir | Douglas-fir | Douglas-fir |
| Hem-fir | Hem-fir | Hem-fir |
| | White fir | Fir |
| | Other fir | |
| Cedar | Western redcedar | Western redcedar |
| | Other cedar | Other cedar |
| | | Yellow cedar |
| | | Cedar |
| Others | Ponderosa pine | Ponderosa pine |
| | Other pine | Other pine |
| | Redwood | Redwood |
| | Eastern white pine | Eastern white pine |
| | Other eastern softwoods | Eastern red pine |
| | | Hemlock |
| | Western white pine | Larch |
| | Sugar pine | Pine |
| | Other western softwoods | Other |

because these have distinct uses and applications. In the absence of monthly data for treated SYP, annually and quarterly treated SYP production statistics were obtained from Southern Forest Products Association, and monthly series were constructed using suitable procedures: a fitted regression, extrapolation, and apportionment.[4]

Annual production data for structural panels (plywood, OSB, and waferboard) were obtained from the Engineered Wood Association (Tacoma, WA). Using monthly proportions of production from unpublished monthly data for structural panels, monthly production numbers were estimated. The monthly import and export statistics for structural panels were drawn from the USITC Data Web.

Dimension lumber price series from Random Lengths Yearbooks were used in the analysis (Table 2).[5] Six groups of softwood products were constructed for the purpose of this analysis—SPF, SYP-U, SYP-R, DF, WSP, and other. Cedar, hem-fir groups, and other lumber were included in the other group, and a volume-weighted average price for cedar, hem-fir, and other species was calculated and used in the analysis. Plywood and OSB were combined into a WSP group, and a volume-weighted average price for plywood and OSB was used in the analysis.[6] Figure 2 shows how the softwood products consumption in the United States changed during the years 1989, 1995, and 2001. Particularly noticeable is the fact that consumption of SPF and WSP dramatically increased, while that of other species and Douglas-fir declined.[7]

## Empirical Results

Most parameters of interest can be obtained from the six cost share equations in Equation 5 without considering the

**Table 2. Softwood lumber products and the prices used in the analysis.**

| Product | Price |
|---|---|
| SPF | SPF, kiln-dried, #1&2, random, delivered to Great Lakes. |
| SYP-U | Southern pine (eastside), kiln-dried, #2, random, net f.o.b. mill. |
| SYP-R | Southern pine, treated, 2×4–12′, #2, random, net f.o.b. treating plant. |
| DF | Douglas-fir, kiln-dried, 2×4, Std&Btr, random, net f.o.b. mill. |
| Hem-fir | Hem-fir (inland Spokane), kiln-dried, 2×4, Std&Btr, random, net f.o.b. mill. |
| Cedars | Western redcedar, green, 2×4, Std&Btr, random, net f.o.b. mill. |
| Other | Fir & larch, kiln-dried, 2×4, Std&Btr, random, net f.o.b. mill. |
| Plywood | Southern plywood, (east) 23/32″, underlayment, C X-Band, T&G, net f.o.b. mill. |
| OSB | OSB, southeast, 23/32″, T&G, net f.o.b. mill. |

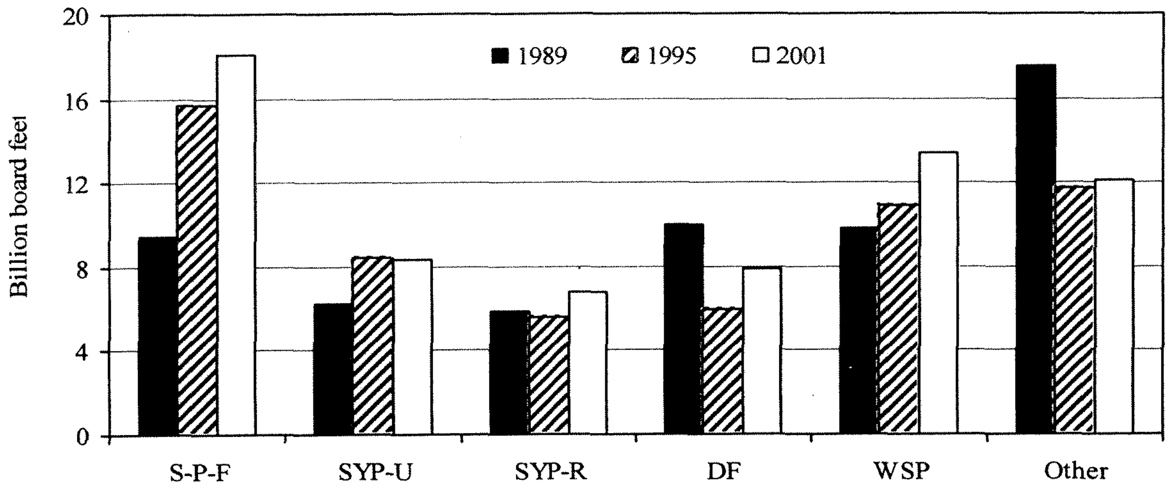


**Figure 2. Softwood lumber products consumption in the United States: 1989, 1995, and 2001.**

total cost function. But this procedure neglects the information contained in the total cost function, because coefficients $\alpha_Q$, $\alpha_{QQ}$, and coefficients for period dummies ($\alpha_{T_2}$ and $\alpha_{T_3}$) cannot be estimated without including the total cost function in the estimation. The optimal procedure is to jointly estimate total cost function and cost share equations. Because errors are contemporaneously correlated, maximum-likelihood estimates for seemingly unrelated regression equations (SURE) were obtained.

Because the cost shares should sum to one, to avoid the problem of singularity of covariance matrix, one cost share equation (the other group) was dropped from estimation. The remaining five cost share equations were estimated by normalizing the prices with respect to the price of the dropped equation. Endogeneity of $Q$ and $P^{S_i}$ can be a problem in the model, as there may be a simultaneous equations bias in the parameters estimated by ordinary least squares. The alternative to this is to use either iterative Zellner-efficient estimation (IZEF) or maximum likelihood estimation (MLE) methods, which are computationally equivalent (Berndt and Christensen 1973). Because a MLE procedure is used, the parameter estimates are also invariant to the dropped equation (Greene 1995). The parameter coefficients and their standard errors for the dropped cost share equation were estimated indirectly using the procedure outlined in Berndt (1991).

### *Estimated Cost Function*

Table 2 reports the estimated cost function coefficients and their standard errors. The function is linear homogeneous in input prices because of the restrictions imposed in Equations 6a through 6d. A well-behaved cost function is concave in the factor prices, and its factor demand functions are strictly positive for positive input prices and a positive output level. However, the translog cost function does not satisfy these properties globally, but can satisfy them locally. To ensure this, the cost function should be monotonically increasing and strictly quasi-concave in input prices and level of output. We found that the monotonicity condition is satisfied at each monthly observation. The quasi-concavity condition is satisfied if the $n \times n$ matrix of substitution elasticities is negative semi-definite (Baardsen 2000). We checked the $6 \times 6$ matrix of elasticities of substitution using both eigenvalue and principal minor methods and found it to be negative semi-definite.[8] Therefore, the estimated cost function is well behaved and consistent with economic theory.[9]

Table 3 shows that 24 out of 40 directly estimated coefficients are different from zero at 5% significance or better. The intercept coefficient for the second period (covering free trade period), $\alpha_{T_2}$ (−0.09), is negative and significant at the 1% level, suggesting that the softwood costs to softwood-utilizing industries decreased significantly in the free trade period over the first period (MOU and duties

**Table 3. Parameter estimates of translog subcost function, US: Jan. 1989 to July 2001.[a]**

| Parameter | Estimate | SE | Parameter | Estimate | SE |
|---|---|---|---|---|---|
| $\alpha_0$ | 7.0240 | 12.732 | $\beta_{RQ}$ | −0.0460** | 0.012 |
| $\alpha_{T_2}$ | −0.0856** | 0.006 | $\beta_{DQ}$ | −0.0131 | 0.008 |
| $\alpha_{T_3}$ | 0.0089 | 0.005 | $\beta_{EQ}$ | 0.0000 | 0.007 |
| $\alpha_Q$ | 0.0710 | 1.653 | $\beta_{T_2S}$ | −0.0822** | 0.011 |
| $\alpha_{QQ}$ | 0.0614 | 0.107 | $\beta_{T_2U}$ | −0.0127 | 0.013 |
| $\alpha_S$ | −0.3217 | 0.200 | $\beta_{T_2R}$ | −0.0424** | 0.009 |
| $\alpha_U$ | −0.3428 | 0.262 | $\beta_{T_2D}$ | −0.0111 | 0.007 |
| $\alpha_R$ | 0.7819** | 0.194 | $\beta_{T_2E}$ | 0.1654** | 0.007 |
| $\alpha_D$ | 0.2824* | 0.129 | $\beta_{T_3S}$ | 0.0370** | 0.013 |
| $\alpha_E$ | 0.2528* | 0.120 | $\beta_{T_3U}$ | 0.0296 | 0.017 |
| $\beta_{SS}$ | 0.0295** | 0.006 | $\beta_{T_3R}$ | −0.0424** | 0.013 |
| $\beta_{SU}$ | 0.0204** | 0.004 | $\beta_{T_3D}$ | −0.0107 | 0.008 |
| $\beta_{SR}$ | −0.0113** | 0.003 | $\beta_{T_3E}$ | −0.0046 | 0.008 |
| $\beta_{SD}$ | −0.0189** | 0.004 | | | |
| $\beta_{SE}$ | 0.0174** | 0.004 | | | |
| $\beta_{UU}$ | 0.0193** | 0.006 | | Indirectly Estimated Coefficients | |
| $\beta_{UR}$ | −0.0137** | 0.004 | $\alpha_O$ | 0.3474 | 0.907 |
| $\beta_{UD}$ | −0.0137** | 0.003 | $\beta_{OO}$ | 0.0741 | 0.038 |
| $\beta_{UE}$ | 0.0237** | 0.003 | $\beta_{OS}$ | −0.0371** | 0.009 |
| $\beta_{RR}$ | −0.0362** | 0.010 | $\beta_{OU}$ | −0.0360** | 0.009 |
| $\beta_{RD}$ | 0.0852** | 0.008 | $\beta_{OR}$ | −0.0231 | 0.016 |
| $\beta_{RE}$ | −0.0008 | 0.009 | $\beta_{OD}$ | −0.0021 | 0.021 |
| $\beta_{DD}$ | −0.0656** | 0.014 | $\beta_{OE}$ | 0.0244 | 0.024 |
| $\beta_{DE}$ | −0.0152 | 0.013 | $\beta_{OQ}$ | −0.0098 | 0.027 |
| $\beta_{EE}$ | −0.0798** | 0.017 | $\beta_{T_2O}$ | −0.0170 | 0.022 |
| $\beta_{SQ}$ | 0.0377** | 0.013 | $\beta_{T_3O}$ | −0.0089 | 0.027 |
| $\beta_{UQ}$ | 0.0312 | 0.017 | | | |

[a] ** and * indicate significance at the 1% and 5% levels, respectively. SE is standard error. The subscripts are: $S$, SPF; $U$, SYP-untreated; $R$, SYP-treated; $D$, Douglas-fir; $E$, wood structural panels; and $O$, other species; $Q$, total quantity of softwood products; $T_2$ and $T_3$ are period dummies.

period). The intercept coefficient for the third period (covering the SLA period), $\alpha_{T_3}$ (0.009), is positive but insignificant, indicating that overall effect of the SLA was similar to the increased levels of softwood costs experienced during the time of the MOU and interim duties.

The interaction terms between period dummies and the softwood product prices show that SPF ($\beta_{T_2S} = -0.08$) and SYP-R ($\beta_{T_2R} = -0.04$) consumption declined significantly in the second period, and consumption of structural panels ($\beta_{T_2E} = 0.17$) increased significantly. In the third period, SPF ($\beta_{T_3S} = 0.04$) consumption increased and Douglas-fir ($\beta_{T_3D} = -0.01$) consumption decreased.

The effect of increased consumption of different softwood products on the total cost is captured by the coefficients of interaction terms between their prices and total quantity of softwood consumption ($Q$). The magnitudes of the coefficients for interaction between softwood product prices and the total quantity consumed also indicate the percentage change in the demand for the respective softwood products when the total quantity of softwood consumption increases by 1%, holding other softwood product prices constant.

### *Elasticities of Substitution*

The Allen partial elasticities of substitution and their standard errors, calculated at the mean monthly levels of estimated cost shares using Equations 7 and 8, are presented in Table 4. All own elasticities of substitution (diagonals) have negative signs, indicating that a curvature condition for the total cost function is satisfied. The results in the first column of Table 4 show the relationship between the main imported softwood product group SPF and the remaining softwood product groups. The SPF product group is unrelated to treated SYP (0.03), Douglas-fir (0.24), and other species (0.31) groups as indicated by insignificant partial elasticities of substitution. However, significant substitution relationships exist between pairs of SPF and untreated SYP, and SPF and engineered wood products. Specifically, a 1% increase in the ratio of the SPF price to that of untreated SYP would increase demand for untreated SYP by 1.46%, while a similar change with respect to WSP would increase demand for WSP by 1.27%.

The negative elasticity of substitution (−0.97, significant at the 10% level) between untreated and treated SYP suggests that they are complements. Looking at the substitution elasticities between untreated SYP and WSP (1.63), and between untreated SYP and SPF (1.46), it appears that untreated SYP is facing more competition from structural panels rather than from SPF. A test of equality of substitution elasticities between untreated SYP and SPF on the one hand, and untreated SYP and WSP on the other, using a procedure for testing a linear restriction outlined in Greene (1993), is rejected at the 10% significance level against the alternative hypothesis that the two elasticities of substitution are not equal.[10] It is also notable that structural panels are proving to be the significant substitutes for untreated SYP, SPF, DF, and "other" lumber species groups.

Our results may not be directly comparable to previous studies because of differences in methodologies and time periods used. These findings—SPF is a significant substitute

**Table 4. Allen partial elasticities of substitution between softwood lumber products, US: Jan. 1989 to July 2001.**[a]

| | SPF | SYP-U | SYP-R | DF | WSP | Other |
|---|---|---|---|---|---|---|
| SPF | −2.2798** | | | | | |
| | (0.80) | | | | | |
| SYP-U | 1.4622** | −4.4573** | | | | |
| | (0.092) | (0.216) | | | | |
| SYP-R | 0.0341 | −0.9728 | −41.5575** | | | |
| | (0.278) | (0.552) | (5.249) | | | |
| DF | 0.2431 | 0.0765 | 22.4749** | −17.6630** | | |
| | (0.149) | (0.191) | (1.941) | (1.601) | | |
| WSP | 1.2733** | 1.6256** | 0.9226 | 1.7037** | −4.7177** | |
| | (0.055) | (0.083) | (0.901) | (0.605) | (0.308) | |
| Other | 0.3081 | −0.1301 | −1.7137 | 0.8817 | 1.5261** | −2.1647* |
| | (0.175) | (0.282) | (1.928) | (1.147) | (0.512) | (0.971) |

[a] ** and * indicate significance at the 1% and 5% levels, respectively. Figures in parentheses are standard errors: $SE(\sigma_{ij}) = SE(\beta_{ij})/m_i m_j$ (Binswanger 1974, Pindyck 1979).

only to untreated SYP and engineered wood products, but unrelated to treated SYP, DF, and other species comprising about 71% of domestic softwood lumber production or 76% of domestic softwood lumber consumption (excluding SPF and engineered wood products) in the United States in 2001—differ from Lewandrowski et al. (1994), who find that the Canadian lumber is a substitute for softwood lumber in all regions (thus implying all species) in the United States.

It is particularly interesting to note how the partial elasticities of substitution between SPF (which is mainly imported from Canada) and the other lumber species/products change over time. Table 5 shows these partial elasticities of substitution estimated using average annual shares of various lumber species. The column labeled SPF*SYP-R gives the story of transformation of the relationship between SPF and treated SYP from being one of substitutes as indicated by positive and significant partial elasticities of substitution during 1989–1993 to being unrelated or even moderate complements after 1995. Thus, although these species groups were unrelated in the whole study period, their relationship changed from one of substitution to complementarity over the study period.

### *Price Elasticities of Demand*

All of the own-price elasticities of demand for softwood products, which are shown on the diagonal of Table 6, have the correct sign. Own-price elasticities of demand for SPF, untreated SYP, and other species are less than one, while those for treated SYP, DF, and WSP exceeded one. These

**Table 5. Allen partial elasticities of substitution between SPF and other softwood lumber products, US: Jan. 1989 to July 2001.**[a]

| Year | SPF*SPF | SPF*SYP-U | SPF*SYP-R | SPF*DF | SPF*WSP | SPF*other |
|---|---|---|---|---|---|---|
| 1989 | −2.3066** | 1.4988** | 0.4446** | 0.2616 | 1.3215** | 0.3324* |
| | (0.082) | (0.098) | (0.160) | (0.145) | (0.065) | (0.169) |
| 1990 | −2.2985** | 1.4979** | 0.3880* | 0.3169* | 1.3134** | 0.3164 |
| | (0.081) | (0.098) | (0.176) | (0.134) | (0.063) | (0.173) |
| 1991 | −2.3627** | 1.5251** | 0.4285** | 0.2946* | 1.3224** | 0.3225 |
| | (0.085) | (0.104) | (0.165) | (0.139) | (0.065) | (0.171) |
| 1992 | −2.3382** | 1.5111** | 0.4135* | 0.2850* | 1.3301** | 0.3477* |
| | (0.083) | (0.101) | (0.169) | (0.141) | (0.067) | (0.165) |
| 1993 | −2.3673** | 1.5292** | 0.4273** | 0.2151 | 1.3076** | 0.3258 |
| | (0.085) | (0.104) | (0.165) | (0.154) | (0.062) | (0.171) |
| 1994 | −2.6117** | 1.5648** | 0.1377 | 0.1655 | 1.2727** | 0.2308 |
| | (0.100) | (0.111) | (0.248) | (0.164) | (0.055) | (0.195) |
| 1995 | −3.4329** | 1.7461** | −1.5863* | −0.0586 | 1.2537** | −0.0300 |
| | (0.163) | (0.147) | (0.745) | (0.208) | (0.051) | (0.261) |
| 1996 | −2.2589** | 1.4494** | −0.6947 | 0.1456 | 1.2387** | 0.2804 |
| | (0.079) | (0.089) | (0.488) | (0.168) | (0.048) | (0.182) |
| 1997 | −1.9749** | 1.3838** | −1.0669 | 0.2650 | 1.2461** | 0.3390* |
| | (0.064) | (0.076) | (0.595) | (0.145) | (0.050) | (0.167) |
| 1998 | −1.8968** | 1.3521** | −2.3389* | 0.3623** | 1.2655** | 0.3623* |
| | (0.061) | (0.069) | (0.961) | (0.125) | (0.054) | (0.161) |
| 1999 | −1.8875** | 1.3476** | −1.0224 | 0.2826* | 1.2722** | 0.3872* |
| | (0.060) | (0.069) | (0.582) | (0.141) | (0.055) | (0.155) |
| 2000 | −1.9248** | 1.3609** | −1.1230 | 0.2914* | 1.2703** | 0.3869* |
| | (0.062) | (0.071) | (0.611) | (0.139) | (0.055) | (0.155) |
| 2001 | −2.6622** | 1.5447** | −1.5671* | 0.0646 | 1.2334** | 0.1809 |
| | (0.103) | (0.107) | (0.739) | (0.184) | (0.047) | (0.207) |

[a] ** and * indicate significance at the 1% and 5% levels, respectively. Figures in parentheses are standard errors.

Table 6. Own- and cross-price elasticities of demand for softwood lumber products, US: Jan. 1989 to July 2001.[a]

| Percentage effect on the quantity demanded of | For a 1% change in the price of | | | | | |
|---|---|---|---|---|---|---|
| | SPF | SYP-U | SYP-R | DF | WSP | Other |
| SPF | −0.6196** | 0.2365** | 0.0015 | 0.0223 | 0.2985** | 0.0608 |
| | (0.022) | (0.015) | (0.012) | (0.014) | (0.013) | (0.035) |
| SYP-U | 0.3985** | −0.7189* | −0.0420 | 0.0070 | 0.3811** | −0.0257 |
| | (0.025) | (0.035) | (0.024) | (0.018) | (0.020) | (0.056) |
| SYP-R | 0.0093 | −0.1569 | −1.7949** | 2.0646** | 0.2163 | −0.3384 |
| | (0.076) | (0.089) | (0.234) | (0.178) | (0.211) | (0.381) |
| DF | 0.0661 | 0.0123 | 0.9707** | −1.6226** | 0.3994** | 0.1741 |
| | (0.040) | (0.031) | (0.084) | (0.147) | (0.142) | (0.227) |
| WSP | 0.3460** | 0.2622** | 0.0398 | 0.1565** | −1.1059** | 0.3014** |
| | (0.015) | (0.013) | (0.039) | (0.056) | (0.072) | (0.101) |
| Other | 0.0837 | −0.0210 | −0.0740 | 0.0810 | 0.3577** | −0.4275* |
| | (0.048) | (0.045) | (0.083) | (0.105) | (0.120) | (0.192) |

[a] ** and * indicate significance at the 1% and 5% levels, respectively. Figures in parentheses are standard errors: $SE(\eta_{ij}) = SE(\beta_{ij})/m_i$ (Binswanger 1974, Pindyck 1979).

own-price elasticity estimates are comparable with Lewandrowski et al. (1994) elasticity estimates of −0.82 for Canadian lumber (mainly SPF) and −0.67 for southern pine (which was mainly untreated in the length of their data set). The own-price elasticity of demand for structural panels (WSP) is comparable to the McKillop et al. (1980) estimate of −0.67 for plywood, Spelter's (1984) estimates of −0.83 for plywood and −0.56 to −0.86 for structural particleboard, and Adams and Haynes' (1996) estimate of −0.59 for OSB.

The cross-price elasticities of demand between all pairs of softwood products are less than one. The Douglas-fir and untreated SYP pair has the highest cross-price elasticity of demand (0.97). If we look at the main softwood products individually, a 1% increase in the price of SPF lumber results in the largest increase in the quantity demanded of untreated SYP (0.40%), followed by WSP (0.35%), other things being equal. Similarly, a 1% increase in the price of untreated SYP produces the largest increase in the quantity demanded of structural panels (0.26%), followed by SPF (0.24%), but also produces a largest decrease in the quantity demanded of treated SYP (−0.16%, significant at the 10% level). On the other hand, a 1% increase in the price of structural panels would result in the increase in the quantity demanded of Douglas-fir, untreated SYP, other species, SPF, and treated SYP in that order.

## Conclusions and Implications

We sought to determine whether SPF lumber mainly imported from Canada is a substitute or a complement to softwood lumber produced in the United States, with a particular focus on southern yellow pine, which has emerged since the 1980s as encompassing two distinct products. Monthly US consumption data from Jan. 1989 to July 2001 on six groups of softwood products were analyzed by estimating the restricted translog cost function and cost share equations simultaneously using a maximum likelihood procedure.

The results show that the main imported Canadian species group SPF is behaving like an independent market and is largely unrelated to the domestically produced treated southern yellow pine, Douglas-fir, and other species groups. Interestingly, the relationship between SPF and treated SYP lumber has changed over time from being substitutes to being unrelated or even complements. However, the SPF group competes with the domestically produced untreated southern yellow pine and structural panels and thus appears to be a significant substitute for these products in the United States. In addition, untreated southern yellow pine is facing more severe competition from structural panels than from SPF imports from Canada.

Joint analysis of three time periods indicates that the softwood costs to the US softwood-utilizing industries were significantly lower in the free trade period than in the SLA period and the period when the MOU, interim duty, and countervailing duties were in force. The lower costs in free trade might have happened because the larger volume coupled with lower prices of Canadian SPF imports competed not only with untreated SYP lumber, but also with engineered wood products. With the imposition of the MOU, countervailing and interim duties, and SLA, we found higher costs reigned. The findings of Wear and Lee (1993), Lindsay et al. (2000), and Zhang (2001) that softwood lumber costs have increased for US consumers support the results of this analysis.

The policy implications of this study are fourfold. First, the imported softwood product (SPF) appears to be unrelated to some 71% of domestically produced softwood lumber, which includes treated SYP, Douglas-fir, and other species in the United States. SPF imports are fulfilling the increasing needs of softwood lumber for expanding the US housing construction, remodeling, and repair industry in the wake of restrictions on timber harvesting on federal lands in the Pacific Northwest and of reduced supply from other regions in the United States. The results support the contention of US consumer groups that Canadian lumber imports are specifically demanded in the construction of new homes and the upgrade and repairs of existing homes in America. They also validate the argument that, to some degree, Canadian imports are not substitutes for US production. On the other hand, Canadian imports are substitutes for untreated southern yellow pines, implying that some domestic lumber producers are vulnerable to Canadian lumber imports.[11]

Second, given that SPF is a substitute for and directly competes with untreated southern yellow pine, it is not surprising to see that major political advocates for restricting Canadian lumber imports are from the US South. Even so, structural panels compete with both untreated SYP and SPF, and untreated southern yellow pine is facing greater competition from these structural panels than from SPF. These facts were also noted by some consumer advocates who indicated that the principal competitive threat to the use of SYP comes not from imports, but from engineered wood products such as wood I-joists and composite materials (Rayburn 2002). Although we did not include wood I-joists and composite materials but included only plywood and OSB in the wood structural panels group in the analysis, the results indicate competition from the engineered wood products to untreated SYP, SPF, and the other species product group, in that order. Perhaps, then, attracting more engineered wood products mills to the US South could help alleviate the economic development problem associated with increasing softwood lumber imports.

Third, US lumber producers' efforts to seek a change in trade policy as a means of obtaining a reduction in the share of Canadian imports and thereby increasing the share of domestically produced lumber in the US lumber consumption have proved effective in the wake of strong demand for housing in the United States in the 1990s. The US softwood lumber production increase of 14% from 1995 to 1999, roughly coinciding with a period of the SLA, indicates a trade policy-induced increase in the competitiveness of the US lumber industry. These increased shares surely have led to greater benefits enjoyed by producers of untreated southern pine lumber and manufacturers of engineered wood products. The Canadian share of US softwood lumber consumption, on the other hand, has been steady, and Canadian export of softwood lumber to the United States increased by 7.5%, in spite of the SLA. However, this strategy of protecting the domestic sector could prove detrimental to secondary US softwood manufacturers and to hardwood furniture manufacturers when their products do not directly compete with Canadian lumber imports. Given that demands for those products are positively related to housing demand and given that housing demand is negatively affected by higher input prices, higher Canadian spruce-pine-fir import prices lead to lower demand for other products (e.g., Adams 2003).

Finally, a more recent tariff imposed on Canadian lumber imports (in May 2002) has not been successful in lifting lumber prices in the United States (although the counter factual—absent the tariff, some domestic prices might have been lower—has not been proven). Furthermore, Canada has taken the softwood lumber dispute to World Trade Organization and North American Free Trade Agreement, leaving the issue of future trade restrictions uncertain. With these kinds of clouds and uncertainty still looming, and given our new empirical results showing only incomplete competition between SPF and domestically produced lumber, US wood product producers may profitably adopt an alternative strategy. This would include cost cutting, greater investment in research and development and in new wood engineering technologies, and other inwardly focused investment approaches, yielding more certain long-run returns than those obtained by head-to-head product competition and controversial short-run policy fixes. In the near-term, trade actions against Canadian lumber could benefit some lumber producers and even enhance the profitability of some in the US lumber industry. However, the benefits enjoyed by the industry from such trade actions are likely to be outweighed in economic terms by the costs of such actions on the aggregate US economy.

## Endnotes

[1] We have chosen the Allen elasticity of substitution for its popularity and also because it can distinguish complementarity from substitutability between inputs more frequently than other forms of elasticity of substitution. Other measures of elasticity of substitution include the Morishima elasticity of substitution and shadow elasticity of substitution (Chambers 1988). However, Fuss et al. (1978) argue that there is no omnipotent measure of elasticity of substitution and the selection of a particular definition should depend on the question asked.

[2] The monthly shares of lumber production by species were estimated by instrumental variables, with instruments of housing starts, US gross domestic product in 1996 real dollars, the US-Canada exchange rate, species-specific linear time trends, and a lagged dependent variable (lagged share) as independent variables. The explanatory powers ($R^2$s) of these equations were: spruce-pine-fir (82%), southern yellow pine (93%), Douglas-fir (90%), hem-fir (80%), cedar (63%), and other species (90%). Seasonality in production was incorporated into these estimates by using monthly seasonality variations observed for all softwood lumber. The seasonal variations were obtained by estimating an ordinary least squares equation of total softwood lumber production as a function of the lagged dependent variable, monthly dummies, a linear time trend, housing starts, US gross domestic product in 1996 in real dollars, and the US-Canada exchange rate. The results obtained using these instrumented and seasonality-augmented shares were similar to those that we found when we imputed monthly production data for different species by simply assuming that the species proportion was the same for all months in a particular year. Additional details of the instrumented estimated equations are not provided here to conserve space but can be obtained from the authors on request.

[3] Under the HTS system, export and import data pertaining to 10-digit HTS codes 4407100001 to 4407100093 belonging to various softwood lumber species were compiled. Data were for the period from Jan. 1989 to July 2001.

[4] The quarterly treated SYP production statistics were available for the years 1993 to 2001. Because the data showed apparent seasonality, a regression equation, including a time trend and seasonal dummy variables, was fitted on the quarterly proportions of the treated SYP production data. The fitted equation was: $1033.9 + 45.18*T + 174.0*D_1 + 576.67*D_2 + 384.11*D_3$, (adjusted $R^2 = 0.90$), where $T$ is time in years starting $1993 = 1$, $D_1$ to $D_3$ are dummy variables representing quarters 1 to 3, and the intercept representing quarter 4. The predicted quarterly proportions for the years 1989 to 1992 were determined by extrapolation using the predicted regression equation, and quarterly production numbers for treated SYP were calculated from the annually treated SYP production data. From these quarterly numbers, monthly production data for treated SYP were estimated using the monthly proportions of total SYP production. Because SYP lumber imports were a tiny percent of total SYP lumber consumed, imports of treated SYP were assumed to be nil. The monthly export quantities for treated lumber were taken from the USITC Data Web. The monthly export numbers for treated lumber for all species were reported under HTS species code 4407100005 (1989 to 1996) and 4407100002 (1997 to 2001). Out of this exported treated lumber, 85% was assumed to be of SYP-treated lumber (GC&A 1990).

[5] The results were identical with nominal or real prices. Augmented Dickey-Fuller tests (the $t$-test and the rho-test) were conducted by using a general-to-specific model selection strategy, beginning at 18 lagged difference terms and successively reduced in order until the minimum of the Akaike Information Criterion was found (see Hall 1994). Both the $t$-test and the rho-test produced results that rejected the unit root null at 10% nominal significance. This was true for both deflated and undeflated price series. Additionally, the more powerful test against a false unit root null, the rho-test, typically rejected the unit root null at 5% nominal significance.

[6] The basic reported units for plywood and OSB were MSF (thousand square feet) on a 3/8″ basis. To ensure uniformity with the units of lumber in MBF in the dependent variable in the total cost function, plywood and OSB quantities were converted into MBF using conversion factor 2.667 MSF $MBF^{-1}$. For import and export data that were reported in cubic meters, the conversion factors used were 0.424 MBF $m^{-3}$ for softwood lumber, and 1.130 MSF $m^{-3}$ of 3/8″ basis for plywood and OSB.

[7] These changes can be attributed to harvest reductions in the US Pacific Northwest, an increasing share of small diameter logs used in mills, and the continued strength of the US housing market.

[8] The eigenvalues were: 0.00, –2.11, –3.29, –4.78, –7.52, and –55.15, and the determinants of the principal minors were: –2.28, 8.01, –330.89, 1805.15, –2625.15, and 0.00.

[9] The results were highly sensitive to specification. Other specifications were conducted, but none of them could satisfy the theoretical properties of the cost function. Hence, the specification in Equation 4 was retained.

[10] The calculated $t$-value is –1.74 given $df$ = 149 ($n$-$k$ = 151–2).

[11] One reviewer of this article asked that if SPF is unrelated to all these other lumber groups, how could SPF consumption have increased at the same time that US output decreased. As output of US softwood products declined (in the face of the strong demand described), their prices would go up. We have a three-part explanation for this phenomenon. First, there is no evidence that the production or domestic consumption in the United States have declined during the study period (1989 to 2001). In other words, an increase in SPF consumption (and imports) can (and did) occur concurrently with an increase in production and consumption of domestically produced lumber, if the output effect on demand for the aggregate dominates the substitution effect within the aggregate. Second, as mentioned, SPF is substitute for untreated SYP. If investment (and disinvestment) in plants producing treated SYP is small or if there are no barriers to entry or exit in producing treated SYP from untreated SYP, producers could switch back and forth between treated and untreated SYP. For example, if demand for treated SYP goes up due to an increase in housing starts, the price of treated SYP will go up. This means that, everything else being equal, the production of untreated SYP will go down. Less untreated SYP production in that situation would therefore lead to higher SPF imports. Third, this study is based on marginal analysis. One cannot assume that a large (say 10–20%), abrupt decrease or increase in US domestic lumber production and consumption would not have an impact on SPF, because we found that SPF imports are substitutes for 29% of domestically produced lumber.

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