

Incidence of the 1996 U.S.–Canada Softwood Lumber Agreement among Landowners, Loggers, and Lumber Manufacturers in the U.S. South

Yanshu Li and Daowei Zhang

Abstract: A framework was developed to estimate the welfare incidence of the 1996 U.S.–Canada Softwood Lumber Agreement among producers in two-processing-stage markets—timberland owners, loggers, and lumber manufacturers—in the U.S. South. Timberland owners are the largest beneficiary whereas lumber manufacturers are the second and loggers the least. Empirically, without considering substitution effects among production inputs, timberland owners have 47.4% of total incremental producer surplus, whereas lumber manufacturers have 39.4% and loggers 13.2%. When the substitution effects are considered, timberland owners gain slightly less whereas lumber manufacturers and loggers gain slightly more. *FOR. SCI.* 52(4):422–431.

Key Words: Welfare incidence, two-processing-stage variable-proportion model, probability distributions for parameters.

THE SOFTWOOD LUMBER TRADE DISPUTE between the U.S. and Canada is generally recognized as the longest and largest trade dispute between these two countries. Approximately US\$6–7 billion worth of Canadian softwood lumber goes to the U.S. annually. Previous studies have addressed welfare impacts of trade restriction measures associated with the dispute (e.g., Boyd and Krutilla 1987, Wear and Lee 1993, Zhang 2001, Kinnucan and Zhang 2004). Recently, Zhang (2006) estimates that the U.S. producers of softwood lumber gained about \$2.56 in the five years under the 1996 U.S.–Canada Softwood Lumber Agreement (SLA). However, no estimates are available on how the gains in producer welfare are distributed among landowners, loggers, and lumber manufacturers, who are the producers of stumpage, logs, and lumber in two stages of processing (log harvesting and lumber manufacturing) markets.

This issue is of considerable importance in public policy and corporate strategic planning. For example, after leading for 15 years in fighting against Canadian softwood lumber imports, Georgia-Pacific Corporation (GP) left, in 2001, the U.S. Coalition for Fair Lumber Imports (the Coalition), which is the main industry body lobbying for restricting Canadian lumber imports. GP's stated rationale for this decision was that it sold all of its 5.8 million acres of timberland, implying that it would not benefit as much from the fight against Canadian lumber imports. However, GP still owns and operates 33 softwood lumber mills and is one of the largest softwood lumber manufacturers in the U.S. The question is how much GP benefits as a landowner and lumber manufacturer versus as a pure lumber manufacturer

from trade restriction measures such as the SLA, which was sought by the Coalition and which greatly benefited all producers associated with lumber production in the U.S. In other words, how is the SLA-induced incremental welfare distributed among landowners, loggers, and lumber manufacturers?

The purpose of this research is to estimate the incidence of the SLA among U.S. producers associated with lumber production through vertical related markets. To that end, we need to generate explicit formulas for estimating welfare size and distribution in a two-processing-stage market system. We believe that the generation of these formulas constitutes a theoretical contribution to the forest economics literature as well. The results of this study may provide a better understanding of the economic impacts of the SLA or any other trade restriction measures and help stakeholders in their decisionmaking.

Although welfare estimates of the SLA are often on national scale, the linkage among stumpage, log, and lumber markets can be best studied at regional level because narrower range of supply elasticity estimates will provide more accurate welfare impact estimates. Furthermore, the softwood supply from public forest in the western U.S. may be affected by factors other than market forces. In this article, we choose the U.S. South [1], where private forests dominate, for our estimation. We decompose the welfare impacts of the SLA among southern softwood landowners, loggers, and lumber manufacturers.

The main finding of the present study is that producers associated with softwood lumber production did not benefit equally from the SLA. Timberland owners are the largest

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beneficiary of the SLA whereas lumber manufacturers are the second and loggers the least. Furthermore, the elasticities of timber, log, and lumber supply play a role in determining the vertical distribution of the total welfare effect. The next section presents a brief review of literature, followed by a description of a simplified model under fixed-proportion assumption. The section entitled, Two-Processing-Stage Variable-Proportion Model, relaxes this assumption and provides a variable-proportion model that allows substitution between inputs. The subsequent section presents data and results using two different models, and the final section concludes.

Literature Review

Theoretical and empirical studies on benefit distribution among multimarkets have been applied to research benefit distribution, trade policy, and advertisement impacts. Alston (1991) provides an extensive literature review of research benefit distribution in a multimarket setting. Early studies are mostly based on the assumption of fixed proportion between final product and input by using a concept of processing margin (e.g., Wiseman and Sedjo 1981, Freebairn et al. 1982), which can be a constant absolute value regardless of quantities of production, a constant percentage of product price, or a combination of a constant and a constant percentage (Waugh 1964, Holley 1970, Haynes 1977). In the case of constant absolute margin, the supply of processing service is assumed to be perfectly elastic, and the demand elasticity for raw material is equal to the product of raw material cost share and demand elasticity of the processed product. In the case of constant percentage margin, the demand elasticities for raw material and final product are the same (Haynes 1977). Under the assumption of fixed proportion, incremental benefits are distributed according to the elasticities of consumer demand and supply in each stage. In general, the more inelastic the supply in one stage is relative to that in other stages, the greater the share of gains going to the producers in the stage. However, the distribution of benefits is independent of the stage at which the price change actually takes place (e.g., Freebairn et al. 1982, Wohlgenant 1993).

Under fixed-proportion approach, the elasticity of substitution between two inputs—raw materials and processing margin—is zero. One of the weaknesses of this approach is lack of theoretical justification for processing margin. Gardner (1975) states, “. . . no simple markup pricing rule—a fixed percentage margin, a fixed absolute margin, or a combination of the two—can in general accurately depict the relationship between the farm and retail price.” Moreover, the model may generate controversial prediction under imperfect competition (Cowling and Waterson 1976, Berck and Rausser 1981, Wohlgenant and Haidacher 1989).

By relaxing the zero elasticity of substitution assumption and following Muth's equilibrium displacement approach, Alston and Scobie (1983) construct a model in a two-factor one-product competitive market setting. They show that, in a variable-proportion model, benefit distribution depends

not only on demand and supply elasticities as in the case of fixed-proportion model, but also on the elasticity of substitution between inputs and the nature of price changes. Their model has since been used and extended by other researchers. Freebairn et al. (1983) extend the model by assuming biased technical change. Martin and Alston (1994) build a model from the perspective of dual approach. Several recent studies focus research gains under imperfect market settings (Huang and Sexton 1996, Alston et al. 1997, Paarlberg and Lee 2001).

Most previous studies are in the context of one-stage processing (e.g., Freebairn et al. 1982, 1983, Mullen et al. 1989, Kinnucan and Miao 2000). Although Holloway (1989) extends the model by Alston and Scobie (1983) to two processing stages, he only considers the welfare impacts on farmers from change in processing supplies. In this study, we attempt to establish a framework to investigate the welfare size and distribution associated with a price change due to an exogenous supply or demand shock, to producers at all stages and to final consumers in a two-processing-stage market system.

A Two-Processing-stage Fixed-Proportion Model for Softwood Lumber

At the first stage, a group of softwood landowners *A* supply stumpage *f* to a group of loggers *B* who combine it with harvesting services *h* (logging, transportation costs, etc.) to produce an intermediate good, delivered logs *g*. At the second stage, a group of lumber manufacturers *C* combines logs *g* with processing inputs *c* to produce the final product *r*. Markets of other input factors for delivered logs and for lumber production (i.e., labor, capital, and energy used in logging and transporting services and in sawmills) are assumed to be exogenous and perfectly elastic. In addition, all supply and demand curves are assumed to be linear in relevant ranges. Finally, competitive market clearings are assumed.

Harvesting margin and processing margin are used to model the relationship between factor and product market. Harvesting margin is defined as the price spread between per unit-delivered log and stumpage. The unit is the amount of log (and stumpage) used for producing one unit (one thousand board feet, mbf) of lumber. Processing margin is the price difference between per unit log and lumber, also measured in mbf lumber.

The relationship among these markets is illustrated in Figure 1. S_a ($a = r, g, f$), is the supply of good *a*, or softwood lumber, log, and stumpage respectively. D_a is the original (market or derived) demand for good *a*. Let Q_a and P_a denote quantity and price of good *a*, respectively. And let Q_a^0 and P_a^0 be the initial equilibrium quantity and price of good *a*, respectively.

Figure 1 also shows the market effects of a vertical parallel demand shift in lumber market (as the SLA) to all related markets. When demand for lumber increases to D'_r , the derived demands for log and stumpage shift to D'_g and

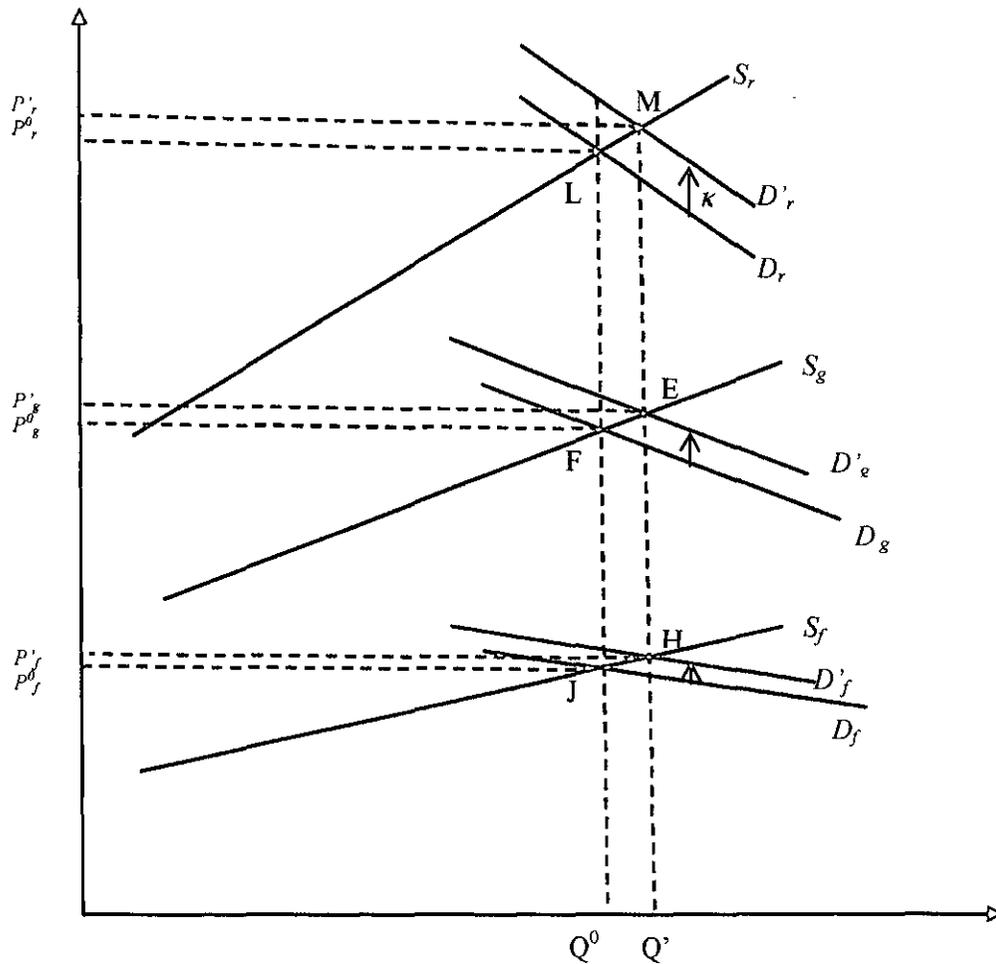


Figure 1. Chain effects of parallel demand shift in the lumber market.

D'_f respectively. The new equilibrium prices for lumber, log, and stumpage become P'_r , P'_g , and P'_f .

Under the assumption of fixed-proportion, the model can be characterized as

$$\text{Lumber Demand: } P_r = b_1 + d_1 Q_r \quad (1)$$

$$\text{Lumber Supply: } P_r = b_2 + d_2 Q_r \quad (2)$$

$$\text{Processing Margin: } PM = \alpha_1 + \beta_1 P_r \quad (3)$$

$$\text{Harvesting Margin: } HM = \alpha_2 + \beta_2 P_g \quad (4)$$

$$P_r = P_g + PM \quad (5)$$

$$P_g = P_f + HM \quad (6)$$

where b_1 , d_1 , b_2 , d_2 , α_1 , β_1 , α_2 , β_2 are parameters to be estimated; and β_1 and β_2 are coefficients of processing margin and of harvesting margin, respectively.

The changes in equilibrium prices and quantities in different markets from a parallel shift of demand in lumber market can be characterized as

$$EP_r = \frac{dP_r}{P_r^0} = \frac{\eta_r \kappa}{\eta_r - \epsilon_r} \quad (7)$$

$$EQ_r = \frac{dQ_r}{Q_r^0} = \frac{\epsilon_r \eta_r \kappa}{\eta_r - \epsilon_r} \quad (8)$$

$$dP_r = (1 - \beta_1) dP_r = P_r^0 (1 - \beta_1) EP_r \quad (9)$$

$$dP_f = (1 - \beta_1)(1 - \beta_2) dP_r = P_r^0 (1 - \beta_1)(1 - \beta_2) EP_r \quad (10)$$

where E denotes relative changes (i.e., $Ex = dx/x$) and d denotes differential. EP_r and EQ_r are the relative changes of equilibrium price and quantity of lumber r ; ϵ_r is the supply elasticity of lumber r ; η_r is the demand elasticity of lumber r ; and κ is relative vertical shift of lumber demand with respect to original lumber price (positive when the demand shifts up and negative otherwise).

Harberger's (1971) "three postulates" are invoked so that Marshallian producer and consumer surplus may be used to evaluate the welfare consequences of a given demand shift for lumber. Because logs and stumpage are measured in equivalent lumber units, the quantity change of logs and stumpage are the same as that of lumber. Thus, change in producer welfare in lumber market, which include change in

producer welfare in log and stumpage markets, can be written as

$$\Delta PS_1 = P_r^0 Q_r^0 \left(1 + \frac{EQ_r}{2}\right) EP_r. \quad (11)$$

Change in producer welfare in log market, which include change in producer welfare in stumpage market, can be written as

$$\Delta PS_2 = (1 - \beta_1) P_r^0 Q_r^0 \left(1 + \frac{EQ_r}{2}\right) EP_r. \quad (12)$$

Finally, change in producer welfare in stumpage market is

$$\Delta PS_3 = (1 - \beta_1)(1 - \beta_2) P_r^0 Q_r^0 \left(1 + \frac{EQ_r}{2}\right) EP_r. \quad (13)$$

Following Just and Hueth (1979), the net welfare change for loggers is the difference between producer surplus change in log market and producer surplus change in stumpage market ($P_r^0 EFP_g^0 - P_r^0 JHP_g^0$). Similarly, the net welfare change for lumber manufacturers is the difference between producer surplus change in lumber market and producer surplus change in log market ($P_r^0 LMP_r^0 - P_r^0 EFP_g^0$).

So, the net welfare change for landowner is as shown in Equation 13. The net welfare change for loggers ΔPS_B is [(12) - (13)], or

$$\Delta PS_B = \beta_2(1 - \beta_1) P_r^0 Q_r^0 \left(1 + \frac{EQ_r}{2}\right) EP_r. \quad (14)$$

and the net welfare change for lumber manufacturers ΔPS_C is

$$\Delta PS_C = \beta_1 P_r^0 Q_r^0 \left(1 + \frac{EQ_r}{2}\right) EP_r. \quad (15)$$

When $\beta_1, \beta_2 \in [0, 1]$, the produce surplus changes for three markets have the same sign. Then, the welfare share of landowners, loggers, and lumber manufacturers can be calculated as

$$\text{Landowners' share} = (1 - \beta_1)(1 - \beta_2), \quad (16)$$

$$\text{Loggers' share} = \beta_2(1 - \beta_1), \quad (17)$$

$$\text{Lumber manufacturers' share} = \beta_1. \quad (18)$$

Total welfare impacts for all producers at different market levels are affected by supply and demand elasticity of lumber market, scale of relative vertical shift κ , original equilibrium quantity and prices, and coefficients of margin to product price (β_1, β_2). However, under the assumption of fixed-proportion between inputs, the welfare share for each producer is only affected by the coefficients of margin to product prices.

A Two-Processing-Stage Variable-Proportion Model

As discussed earlier, the assumption that the elasticity of substitution between inputs is zero may be too extreme. Empirically, the substitution among inputs in either lumber or log production exists (e.g., Stier 1980, Spelter 1992).

This section models the marketing system of softwood lumber by relaxing the fixed-proportion assumption. Following Muth (1964) and Holloway (1989), the supply and demand of log and lumber markets can be depicted by the following set of equations:

$$Q_r = D(P_r) \quad (1')$$

$$Q_r = \varphi(Q_g, Q_c) \quad (2')$$

$$P_g = P_r \varphi_g \quad (3')$$

$$P_c = P_r \varphi_c \quad (4')$$

$$Q_c = \phi(P_c) \quad (5')$$

$$Q_g = \psi(Q_f, Q_h) \quad (6')$$

$$P_f = P_g \psi_f \quad (7')$$

$$P_h = P_g \psi_h \quad (8')$$

$$Q_f = v(P_f) \quad (9')$$

$$Q_h = \tau(P_h) \quad (10')$$

where, P_i and Q_i denote the price and quantity of good i ($i = f, h, g, c, r$), respectively. Equation 1' is the demand function for lumber, whereas Equations 5', 9', and 10' are factor supply functions for processing input, stumpage, and harvesting input, respectively. They are all assumed to be perfectly elastic. Equations 2' and 6' are production functions of lumber and log respectively. $\theta(\cdot)$ and $\psi(\cdot)$ are both assumed to be linearly homogenous of degree one (see Diewert (1981) for a discussion of this assumption), implying constant returns to scale for the industry. Equations 3', 4', 7', and 8' show that all factors are paid the value of their marginal product.

Differentiating Equations 1' through 10', converting to elasticity forms, and adding exogenous shocks yields, the following system of equations in relative changes and elasticities (for details of derivation, see Appendix):

$$EQ_r = \eta_r(EP_r - \kappa) \quad (1'')$$

$$EQ_r = s_g EQ_g + s_c EQ_c + \delta_1 \quad (2'')$$

$$EP_r = \frac{s_c}{\sigma_1} EQ_g - \frac{s_c}{\sigma_1} EQ_c + EP_g + \delta_1 + \omega_1 \quad (3'')$$

$$EP_r = -\frac{s_g}{\sigma_1} EQ_g + \frac{s_x}{\sigma_1} EQ_c + EP_c + \delta_1 - \frac{s_x}{s_y} \omega_1 \quad (4'')$$

$$EQ_c = \varepsilon_c(EP_c - \gamma_c) \quad (5'')$$

$$EQ_g = s_f EQ_f + s_h EQ_h + \delta_2 \quad (6'')$$

$$EP_g = \frac{s_h}{\sigma_2} EQ_f - \frac{s_h}{\sigma_2} EQ_h + EP_f + \delta_2 + \omega_2 \quad (7'')$$

$$EP_x = -\frac{s_f}{\sigma_2} EQ_f + \frac{s_f}{\sigma_2} EQ_h + EP_h + \delta_2 - \frac{s_f}{s_h} \omega_2 \quad (8'')$$

$$EQ_f = \varepsilon_f(EP_f - \gamma_f) \quad (9'')$$

Table 1. Reduced form solutions to the variable-proportion model

$EP_f = \frac{\Delta_1}{\Delta} \quad (12')$	$EP_h = \frac{\Delta_2}{\Delta} \quad (13')$	$EP_c = \frac{\Delta_3}{\Delta} \quad (14')$
$EQ_f = \varepsilon_f \left(\frac{\Delta_1}{\Delta} - \gamma_f \right) \quad (15')$	$EQ_h = \varepsilon_h \left(\frac{\Delta_2}{\Delta} - \gamma_h \right) \quad (16')$	
$EQ_g = s_f \varepsilon_f \left(\frac{\Delta_1}{\Delta} - \gamma_f \right) + s_h \varepsilon_h \left(\frac{\Delta_2}{\Delta} - \gamma_h \right) + \sigma_2 \quad (17')$	$EQ_c = \varepsilon_c \left(\frac{\Delta_3}{\Delta} - \gamma_c \right) \quad (18')$	
$EP_g = \frac{1}{\sigma_2} \left[\varepsilon_f \left(\frac{\Delta_1}{\Delta} - \gamma_f \right) - \varepsilon_h \left(\frac{\Delta_2}{\Delta} - \gamma_h \right) \right] + \frac{\Delta_1}{\Delta} + \delta_2 + \omega_2 \quad (19')$		
$EP_r = \frac{1}{\eta_r} \left[s_g s_f \varepsilon_f \left(\frac{\Delta_1}{\Delta} - \gamma_f \right) + s_x s_h \varepsilon_h \left(\frac{\Delta_2}{\Delta} - \gamma_h \right) + s_g \delta_2 + s_c \varepsilon_c \left(\frac{\Delta_3}{\Delta} - \gamma_c \right) + \delta_1 \right] + \kappa \quad (20')$		
$EQ_r = s_g s_f \varepsilon_f \left(\frac{\Delta_1}{\Delta} - \gamma_f \right) + s_x s_h \varepsilon_h \left(\frac{\Delta_2}{\Delta} - \gamma_h \right) + s_g \delta_2 + s_c \varepsilon_c \left(\frac{\Delta_3}{\Delta} - \gamma_c \right) + \delta_1 \quad (21')$		

$$EQ_h = \varepsilon_h(EP_h - \gamma_h) \quad (10'')$$

where, γ_j ($j = c, f, h$) is relative vertical changes in the supply of good j . When $\gamma_j > 0$, the supply curve of good j shifts up; when $\gamma_j < 0$, the supply curve of good j shifts down. δ_1 is neutral component of technical change in lumber production, defined as the relative (and equal) change in the marginal products of g and c due to neutral technical change. Accordingly, δ_2 is the neutral component of technical change in logging. ω_1 is factor biased (c -saving) component of technical change in lumber production, defined as the relative change in g 's marginal product, holding output constant for the input quantities used prior to the technical change. ω_2 is the h -saving biased component of technical change in logging, accordingly. σ_1 is the Allen partial elasticity of substitution between g and c in lumber production, and σ_2 is Allen partial the elasticity of substitution between f and h in logging. s_k ($k = f, h, g, c$) is the cost share of input k in production with $s_g + s_c = 1$ for lumber production and $s_f + s_h = 1$ for logging.

To solve this system of equations, it is convenient to eliminate EP_r using Equations 3'' and 4'', eliminate EP_g using Equations 7'' and 8'', and express EQ_i in terms of elasticities, relative price changes, and exogenous shocks. By doing this, it can be reduced to a 3-equation solvable system with variables of EP_f , EP_h and EP_c :

$$\begin{pmatrix} \varepsilon_f(\sigma_2 s_f + \sigma_1 s_h) + \sigma_1 \sigma_2 & (\sigma_2 - \sigma_1) s_h \varepsilon_h & -(\sigma_2 \varepsilon_c + \sigma_1 \sigma_2) \\ -(\eta_r + \sigma_1) s_g s_f \varepsilon_f & -(\sigma_1 + \eta_r) s_f s_h \varepsilon_h & \sigma_1 \eta_r + (\eta_r s_g - s_c \sigma_1) \varepsilon_c \\ -(\sigma_2 + \varepsilon_f) & \varepsilon_h + \sigma_2 & 0 \end{pmatrix} \cdot \begin{pmatrix} EP_f \\ EP_h \\ EP_c \end{pmatrix} = \begin{pmatrix} m_1 \\ m_2 \\ m_3 \end{pmatrix} \quad (11')$$

where

$$m_1 = (\sigma_2 s_f + \sigma_1 s_h) \varepsilon_f \gamma_f - (\sigma_1 - \sigma_2) s_h \varepsilon_h \gamma_h - \sigma_2 (\varepsilon_c \gamma_c + \delta_2) - \sigma_1 \sigma_2 \left(\delta_2 + \omega_2 + \frac{\omega_1}{S_y} \right),$$

$$m_2 = s_x (\sigma_1 + \eta_r) (-s_f \varepsilon_f \gamma_f - s_h \varepsilon_h \gamma_h + \delta_2) + \varepsilon_c \gamma_c (\eta_r s_g - \sigma_1 s_c) - \left(\eta_r \delta_1 - \frac{\eta_r s_g \omega_1}{s_c} - \eta_r \kappa - \delta_1 \right) \sigma_1,$$

$$m_3 = -\varepsilon_f \gamma_f + \varepsilon_h \gamma_h + \frac{\sigma_2 \omega_2}{s_h}.$$

Let T denote as the first matrix of the left-hand side of Equation 11'. Determinant of T is $\Delta = \det(T)$. Δ_n ($n = 1, 2, 3$) is the determinant obtained from Δ by removing the n th column and replacing it by the column vector $m = (m_1, m_2, m_3)'$. The reduced form solutions when $\Delta \neq 0$ are shown in Table 1 as Equations 12' through 21'.

To measure welfare benefits to consumers and producers, it is assumed that supply and demand functions are approximately linear in the range of interest and that the curves shift in parallel as a result of exogenous factors above. The formula to calculate final consumer surplus change ΔCS and producer surplus change ΔPS_j for producer providing input j are

$$\Delta CS = -P_r^0 Q_r^0 (EP_r - \kappa) (1 + 0.5EQ_r), \quad (22')$$

$$\Delta PS_j = P_j^0 Q_j^0 (EP_j - \gamma_j) (1 + 0.5EQ_j). \quad (23')$$

Welfare share of supplier of j in total producer surplus change is

$$W_j = \frac{\Delta PS_j}{\sum_j \Delta PS_j}. \quad (24')$$

Equation 24' shows that, through influencing EP_j , elasticities of substitution between inputs in both processing stages play a role in welfare share of the three producers. However, the effects of elasticities of substitution on welfare distribution are undetermined. Furthermore, the share not only relates to the supply elasticity in their own markets, but also to that of vertical-related producers. Equation 24' is meaningful only when all ΔPS_j have the same sign. One advantage of this model over the one in the previous section is that it can be used to estimate the welfare impacts of

simultaneous changes in supply and demand in different markets.

Data and Results

Parameters

To estimate the welfare impacts using the fixed-proportion model, we need six parameters and (α_1 , α_2 , β_1 , β_2 , softwood lumber supply and demand elasticity) and data for original softwood production and price. Adams and Haynes (1980) estimate supply elasticity of U.S. southern lumber at 0.51. This result is generally consistent with previous studies (Holley 1970, Haynes 1977). A later study (Adams et al. 1988) provides a higher estimate of 0.95. Adams and Haynes (1980) estimate national softwood lumber demand elasticity $\eta_r = -0.174$, which is close to McKillop et al.'s (1980) estimate of -0.173 and Spelter's (1985, 1992) estimate of -0.11 to -0.28 . Adams and Haynes (1980) also derive the softwood demand elasticity for U.S. South at $\eta_r = -0.34$. The average softwood lumber price (\$380.5/mbf) and quantity (14.71 bbf for the U.S. South) in 1995 (Random Lengths 1974–2001) are used as the original equilibrium in this study.

To get estimates for α and β in fixed-proportion models, processing and harvesting margins for the southern softwood lumber industry during 1955 and 2001 are calculated. Lumber prices between 1955 and 1973 are from Adams et al. (1988), and those after 1973 are from Random Lengths (1974–2001). Composite framing lumber price is used as softwood lumber price, which is a weighted average of 10 key softwood items. Log and stumpage prices between 1955 and 1976 are from Ulrich (1988), who use stumpage price data from Louisiana private timberland as a proxy of U.S. South stumpage prices. Log and stumpage prices between 1977 and 2001 are from Norris (1977–2001). Figure 2 shows the nominal price trend of softwood lumber, log, and stumpage for the U.S. South.

According to an industry expert (Camp, W., Director, Market Information Services, Southern Forest Products Assoc., personal communication, June 2003), the softwood log-to-lumber recovery factor in the U.S. South was from

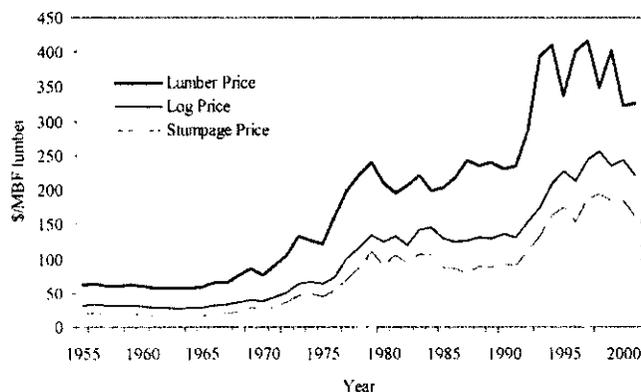


Figure 2. Per equivalent unit softwood lumber, log, and stumpage prices for the U.S. South. Source: Adams et al. (1988) and Norris (1977–2001).

5.55 short tons per mbf in 1970s to 4.75 short tons per mbf in 2002. The recovery factor for each year is obtained by trend adjustment. The harvesting margin is regressed on per equivalent unit log price, and the processing margin is regressed on per unit lumber price. Because there exist high autocorrelation in both models (for example, Durbin-Watson Statistics = 0.95 in the harvesting margin model), we use the default estimator of Limdep (which is the iterative Prais and Winsten algorithm) to correct the autocorrelation.

Table 2 shows the regression results. Both models fit well, and the coefficients except for α_1 are significantly different from zero. These results show that the assumption of constant margin is not realistic because both slope coefficients are significantly different from zero.

Table 3 lists values of additional parameters and variables to estimate welfare impacts of price changes using the variable-proportion model. In the case of the SLA, all exogenous shocks other than demand shift in the lumber market are assumed to be zero, and technical changes in both logging and lumber production are assumed to be neutral.

Probability Distributions for the Parameters

Because some elasticity parameters are chosen from estimates of other studies, it is unknown how robust they are to errors in the parameter values. Traditional sensitivity analysis can only provide a limited picture of the sensitivity of the estimated results (Zhao et al. 2000). A remedy for this problem is to assign some reasonable distributions to these parameters.

Following Zhao et al. (2000) and Piggott (2003), probability distributions are assigned to the elasticity parameters. Considering the characteristics of the parameters, the truncated normal distributions are used to impose theoretic restrictions on them. We assume that there is a higher probability of taking values around the mode, and lower probability of taking values far away.

Because supply elasticities of stumpage, harvesting inputs, log, and processing inputs are derived from that of lumber, distribution of ε_r will determine the distributions of all others. Based on previous studies (Adams and Haynes 1980, Adams et al. 1988), we choose the mode of $\varepsilon_r = 0.70$ and a coefficient of variation (CV) of 20 percent as the

Table 2. Estimation results for harvest margin and processing margin

	Parameter	Coefficient	t-Ratio
Processing Margin Model			
Constant	α_1	6.36	1.23
Lumber Price (\$/mbf, Lumber Tally)	β_1	0.39	16.62
Adjusted R^2		0.86	
Harvesting Margin Model			
Constant	α_2	6.22	3.07
Log Price (\$/mbf, Lumber Tally)	β_2	0.22	14.12
Adjusted R^2		0.93	

Table 3. Values of parameters and variables used in the base scenario under the variable-proportion model

Parameter or Variable	Values	Parameter or Variable	Values
ε_f	0.677 ^a	s_r	0.400 ^a
ε_h	0.750 ^a	s_f	0.763 ^a
ε_g	0.693 ^a	s_h	0.237 ^a
ε_c	0.711 ^a	P_f	266.364 ^b
σ_1	2.044 ^d	Q_f	9.609 ^c
σ_2	2.000 ^d	P_g	348.898 ^b
s_g	0.600 ^a	Q_g	9.609 ^c

a. Derived from the fixed-proportion model for simplicity of comparison. For example, $\varepsilon_f = \varepsilon_r P_f / [(1 - \beta_1)(1 - \beta_2)P_r]$. Elasticity of supply for all other inputs are derived in similar ways.
 b. In \$/mbf. Scribner, from Norris (1995).
 c. In equivalent bbf, estimated based on recovery ratio of lumber in 1995.
 d. According to Gardner (1975), $\sigma_1 \approx d \ln s_g / d \ln (P_r / P_g) + 1 = 2.044$, and $\sigma_2 \approx d \ln s_a / d \ln (P_r / P_a) + 1 = 2.000$.

parameters of the truncated normal distribution. This is equivalent to assuming a 68% probability that ε_r lies between 0.56 and 0.84, and a 95% probability for values between 0.42 and 0.98. The probability distribution for ε_r thus becomes

$$\varepsilon_r \sim N(0.7, 0.14^2 | \varepsilon_r > 0).$$

Similarly, $\eta_r = 0.34$ is chosen as the mode, and a 20% CV is assumed. The 68% probability interval (PI) for lumber demand is (-0.41, -0.27), and the 95% probability interval is (-0.62, -0.06). The distribution for η_r is

$$\eta_r \sim N(-0.34, 0.07^2 | \eta_r < 0).$$

Values of substitution elasticities in two stages in Table 3 are chosen as the modes of σ_1 and σ_2 , respectively. Because no empirical estimates are available for them, a 50% CV is assumed. Thus the probability distributions for σ_1 and σ_2 are

$$\sigma_1 \sim N(2.044, 1.02^2 | \sigma_1 > 0), \quad \sigma_2 \sim N(2.0, 1.0^2 | \sigma_2 > 0).$$

Independence among all stochastic variables is assumed in this study for simplicity.

Incidence of the SLA among Southern Producers associated with Lumber Production

In the simulation, 5,000 sets of parameter values were randomly and independently generated from the distributions specified above. As an example, Figure 3 shows the graph of the probability density functions of annual welfare impact of the SLA on softwood landowners in U.S. South

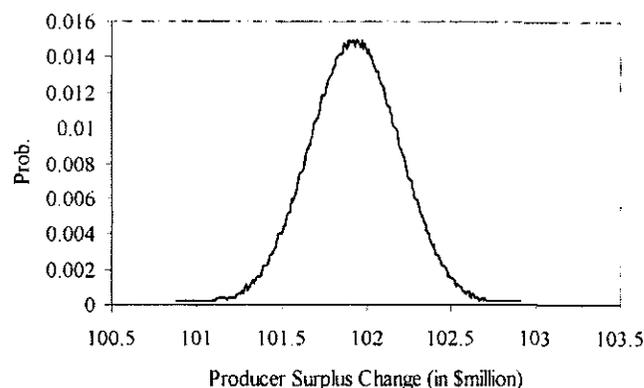


Figure 3. Probability density function of producer surplus change for southern softwood timberland owners from the SLA fixed-proportion model.

by using the fixed-proportion model and an updated estimate of annual 3.8% increase of U.S. softwood lumber price due to the SLA in Zhang (2006) [2]. We observe that the incremental benefit going to timberland owners lies between \$101.3 million and \$102.6 million per year. The jagged nature of the distribution is due to unsmoothed density estimates obtained by joining the midpoints of histogram classes. Figures for other estimates are not shown to conserve space.

Table 4 presents summary statistics and probability intervals from the simulation data using the fixed-proportion model. The interval endpoints are given by the 0.025 and 0.975 empirical percentiles. Because the probability intervals are derived from simulation data, they are different from confidence interval. The mean of total southern lumber producer surplus change associated with the SLA is \$215.2 million per year, and the 95% probability interval (PI) is from \$214.1 million to \$216.3 million. The total benefit for producers associated with southern softwood lumber production for the five years under the SLA would thus be approximately \$1.076 billion [3]. In contrast, our estimate shows that the mean of welfare loss for consumer is about \$463.5 million per year with a wider range of 95% PI (\$204.7 million to \$814.7 million).

Because the share of each producer group in total under the assumption of fixed-proportion is only affected by estimates of β_1 and β_2 , share data are deterministic. The mean of benefits from the SLA for southern timberland owners is \$101.9 million or 47.4% of the total producer benefits. The standard deviation (SD) from the simulation data is 0.27. The 95% PI for the estimates suggests that we have 95

Table 4. Summary statistics for annual welfare impact and distribution of the SLA to related softwood lumber producers in the U.S. South under the fixed-proportion model

	Lumber Manufacturers	Loggers	Timberland Owners
Welfare impact (\$million)			
Mean	84.80	28.50	101.93
SD	0.22	0.07	0.27
95% PI	(84.36, 85.24)	(28.36, 28.65)	(101.41, 102.45)
Share in total Δ PS (%)	39.40	13.24	47.36

percent confidence that the benefits from the SLA for southern softwood timberland owners will be lie between \$101.4 million and \$102.5 million. Similarly, \$84.8 million or 39.4% of total producer benefits go to lumber manufacturers, and \$28.5 million or 13.2% go to loggers on average.

Table 5 presents summary statistics from our simulation results using the variable-proportion model. The estimated welfare benefit for all southern lumber producers is higher and wider-ranged than that of the fixed-proportion model with a mean at \$217.3 million and 95% PI from \$139.3 million to \$308.4 million. The mean of producer surplus change for southern timberland owners is \$100.4 million and the share of the total producer surplus change is 46.2%. The 95% PI for the estimate is from \$64.5 million to \$142.2 million. Compared to the estimates from the fixed-proportion model, the estimate of producer surplus change due to the SLA for timberland owners from the variable-proportion model is 1.4% lower, its share is 2.4% lower, and the 95% PI is somewhat wider. Elasticities of substitution and their variation explain these differences.

The mean of producer surplus change for lumber companies is \$84.8 million and the mean of their share is 39.4%. The 95% PI for benefits is from \$84.4 million to \$85.2 million. The mean of producer surplus change for loggers is \$28.5 million, and the mean of their share is 13.2%. The 95% PI for benefits is from \$28.4 million to \$28.7 million. The estimated loss in consumer surplus is lower in mean (\$441.0 million) and narrower in range (\$349.0 million to \$517.0 million) under the variable-proportion model.

Conclusions and Discussion

In this article, we provide a framework for analyzing welfare size and incidence of a parallel demand shift in competitive two-processing-stage vertically related markets and estimate the incidence of the SLA among producers

Table 5. Summary statistics for annual welfare impact and distribution of the SLA to producers of southern softwood lumber using the variable-proportional model

Producer Surplus Change	Welfare Impact (\$million)	Share in Total Δ PS (%)
Lumber Manufacturers		
Mean	86.60	39.86
SD	17.19	0.08
CV% ^a	19.85	0.21
95% PI	(55.53, 123.09)	(39.63, 39.95)
Loggers		
Mean	30.24	13.91
SD	6.06	0.15
CV%	20.05	1.09
95% PI	(19.27, 43.22)	(13.48, 14.09)
Timberland Landowners		
Mean	100.42	46.23
SD	19.78	0.17
CV%	19.69	0.37
95% PI	(64.51, 142.17)	(45.99, 46.69)

^a CV represents the coefficient of variation, which is the ratio of standard deviation to mean.

associated with softwood lumber production in the U.S. South. Consistent with other studies, our results show that the more inelastic the supply at that stage, the greater share of the producer at one stage among all producer surpluses. Further, both models indicate that timberland owners gain the most among the producer groups, lumber manufacturers are the second beneficiaries, and loggers gain the least. In particular, without considering substitution effects among production inputs, the SLA provided about \$102 million per year in producer surplus for southern softwood timberland owners, \$85 million for lumber manufacturers, and \$28.5 million for loggers. The respective share of the total incremental producer surplus among the three groups is 47.4%, 39.4%, and 13.2%. When the substitution effects among inputs in logging and lumber production are considered, timberland owners gain slightly less whereas the other two groups gain slightly more from the SLA.

It should be noted that the estimated results from the two models do not differ much. This suggests that elasticities of substitution between inputs in production play a modest role in welfare impacts and incidence estimates in this case. The greater the elasticities of substitution in logging and lumber production are, the less the southern timberland owners gain and the more loggers and lumber manufacturers gain from the SLA in terms of both welfare size and incidence.

The results of this study may partially explain why some of the largest timberland owners are the most active members in the Coalition and why GP quit the Coalition after it sold all of its timberland. International Paper is the largest timberland owner and lumber producer in North America, with 10.1 million acres of timberland. Plum Creek (a minor lumber producer) is the second largest with 7.9 million acres. Temple Inland and Potlatch have 2.2 million and 1.5 million acres, respectively. All these firms are active members of the Coalition because they are the largest beneficiaries of trade restriction measures against Canadian lumber.

The framework derived in this study can be used to measure welfare changes in other two-processing-stage market systems due to exogenous (i.e., public subsidies in tree-planting, regulations on timber harvesting and worker safety, and tariffs) and endogenous (i.e., corporate research and development) shocks. This study assumes perfect competitive market structure. Further study may be conducted when the market is imperfect.

Endnotes

- [1] Alabama, Arkansas, Florida, Georgia, Kentucky, Louisiana, Mississippi, Oklahoma, North Carolina, South Carolina, Tennessee, Texas, and Virginia.
- [2] According to Zhang (2006), the anticipated change in lumber price is estimated at \$30 in 1997 U.S. dollars or 7.4%, on average, for the first four years under the SLA. However, the SLA brought negative price and welfare impacts in the fifth year. The price change was about \$16.7 or 3.8% annually for the whole five years under the SLA.
- [3] This is close to the total incremental benefit of \$1.15 billion when one apportions the total benefit for the U.S. based on the South's share of total U.S. lumber production (45% \times \$2.56 billion).

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Appendix: Derivation of Equations 1" to 10"

By total differentiation of Equations 1' to 10',

$$dQ_r = D_{P_r} dP_r \quad (\text{A1})$$

$$dQ_r = \varphi_g dQ_g + \varphi_c dQ_c \quad (\text{A2})$$

$$dP_g = \varphi_g dP_r + P_r d\varphi_g \quad (\text{A3})$$

$$dP_c = \varphi_c dP_r + P_r d\varphi_c \quad (\text{A4})$$

$$dQ_c = \varphi_{P_c} dP_c \quad (\text{A5})$$

$$dQ_g = \psi_f dQ_f + \psi_h dQ_h \quad (\text{A6})$$

$$dP_f = \psi_f dP_g + P_g d\psi_f \quad (\text{A7})$$

$$dP_h = \psi_h dP_g + P_g d\psi_h \quad (\text{A8})$$

$$dQ_f = v_{P_f} dP_f \quad (\text{A9})$$

$$dQ_h = \tau_{P_h} dP_h \quad (\text{A10})$$

Using elasticities and (A1), we can get

$$D_{P_r} = \frac{Q_r \eta_r}{P_r} \quad (\text{A11})$$

Similarly, we can get

$$v_{P_f} = \frac{Q_f \varepsilon_f}{P_f} \quad \text{from (A9),} \quad (\text{A12})$$

$$\tau_{P_h} = \frac{Q_h \varepsilon_h}{P_h} \quad \text{from (A10),} \quad (\text{A13})$$

$$\phi_{P_r} = \frac{Q_c \varepsilon_c}{P_c} \quad \text{from (A5),} \quad (\text{A14})$$

From Equation 3', we can get

$$\varphi_g = \frac{P_g}{P_r} \quad (\text{A15})$$

Similarly,

$$\varphi_c = \frac{P_c}{P_r} \quad \text{from (4'),} \quad (\text{A16})$$

$$\psi_f = \frac{P_f}{P_g} \quad \text{from (7'),} \quad (\text{A17})$$

$$\psi_h = \frac{P_h}{P_g} \quad \text{from (8'),} \quad (\text{A18})$$

Also,

$$d\varphi_g = \varphi_{gg} dQ_g + \varphi_{gc} dQ_c \quad \text{from (A2),} \quad (\text{A19})$$

$$d\varphi_c = \varphi_{cg} dQ_g + \varphi_{cc} dQ_c \quad \text{from (A2),} \quad (\text{A20})$$

$$d\psi_f = \psi_{ff} dQ_f + \psi_{fh} dQ_h \quad \text{from (A6),} \quad (\text{A21})$$

$$d\psi_h = \psi_{hf} dQ_f + \psi_{hh} dQ_h \quad \text{from (A6),} \quad (\text{A22})$$

Using the assumption of constant returns to scale to eliminate all second partials,

$$\varphi_{gg} = -\frac{Q_c \varphi_g \varphi_c}{Q_g \sigma_1 Q_r}, \quad (\text{A23})$$

$$\varphi_{cc} = -\frac{Q_g \varphi_g \varphi_c}{Q_c \sigma_1 Q_r}, \quad (\text{A24})$$

$$\varphi_{gc} = \varphi_{cg} = \frac{\varphi_g \varphi_c}{\sigma_1 Q_r}, \quad (\text{A25})$$

$$\psi_{ff} = -\frac{Q_h \psi_f \psi_h}{Q_f \sigma_2 Q_g}, \quad (\text{A26})$$

$$\psi_{hh} = -\frac{Q_f \psi_f \psi_h}{Q_h \sigma_2 Q_g}, \quad (\text{A27})$$

$$\psi_{fh} = \psi_{hf} = \frac{\psi_f \psi_h}{\sigma_2 Q_g} \quad (\text{A28})$$

Equations 1" to 10" can be derived by plugging Equations (A11) to (A28) into equations (A1) to (A10).