

# The Sustainable Forestry Initiative's impact on stumpage markets in the US South

Roger Brown and Daowei Zhang

**Abstract:** Using survey data and an equilibrium displacement model, we estimate the market and economic impacts of the American Forest and Paper Association's Sustainable Forestry Initiative (SFI) on stumpage markets in the US South. We examine four timber product markets: softwood pulpwood, softwood sawtimber, hardwood pulpwood, and hardwood sawtimber. In each market we calculate changes in producer and consumer welfare using the equilibrium displacement model that accounts for reductions in timber inventories caused by SFI compliance. We find that SFI compliance costs the US South's economy about \$36 million annually. SFI-compliant stumpage producers lose more than \$33 million each year in producer surplus as a result of SFI compliance, and consumers lose about \$12 million annually in consumer surplus due to higher product prices. These costs are offset partially by benefits to nonindustrial private forest producers, non-SFI-compliant industry producers, and public forest producers, who collectively gain about \$10 million in producer surplus annually as a result of higher stumpage prices.

**Résumé :** À l'aide de données d'enquête et d'un modèle de déplacement d'équilibre, les auteurs ont estimé les impacts économiques et sur les marchés de la Sustainable Forestry Initiative (SFI) de l'American Forest and Paper Association sur les marchés du bois sur pied du Sud des États-Unis. Ils ont étudié les marchés de quatre produits du bois : le bois à pâte résineux, le bois de sciage résineux, le bois à pâte feuillu et le bois de sciage feuillu. Pour chaque marché, ils ont calculé les changements dans le bien-être des producteurs et des consommateurs à l'aide du modèle qui tient compte des réductions dans les inventaires de bois causées par l'adhésion à la SFI. Ils constatent que le fait de se conformer à la SFI coûte à l'économie du Sud des États-Unis environ 36 millions de dollars annuellement. Les producteurs de bois sur pied qui se conforment à la SFI perdent plus de 33 millions de dollars chaque année en surplus des producteurs en se conformant à la SFI et les consommateurs perdent environ 12 millions de dollars en surplus des consommateurs à cause du prix plus élevé des produits. Ces coûts sont partiellement compensés par des bénéfices aux producteurs de forêt privée non industrielle, aux producteurs industriels qui ne se conforment pas à la SFI et aux producteurs sur forêt publique qui collectivement enregistrent annuellement un gain d'environ 10 millions de dollars en surplus des producteurs à cause des prix du bois sur pied plus élevés.

[Traduit par la Rédaction]

## Introduction

Forest certification has emerged in recent decades as a means to ensure global forest sustainability. In 1993 environmental groups formed the Forest Stewardship Council (FSC), a nonprofit umbrella organization that provides independent certification of forest practices which comply with principles of sustainability. At the same time, several large US wood product retailers (e.g., Home Depot and Lowe's) began to consider the economic and public relations benefits of corporate policies that favored sustainably grown wood products. Such considerations, if implemented, threatened to reshuffle market shares among industrial timber companies, favoring those that offered wood products certified as produced from sustainably grown forests (Stevens et al. 1998).

In the face of such environmental pressures and potential retail demand changes, the American Forest and Paper Association (AF&PA) responded in 1994 with its own certification program, the Sustainable Forestry Initiative (SFI). The SFI program requires that AF&PA member companies protect water quality, maintain wildlife habitat, ensure reforestation, preserve wildlife biodiversity, protect lands of special ecological significance, and minimize the visual impact of harvesting on company-owned forestland. For instance, the SFI program requires that member companies meet or exceed all established best management practices (BMPs) approved by the US Environmental Protection Agency. BMPs include minimum no-harvest zones around rivers and streams as well as limited clear-cut style harvesting.

The economic and environmental impacts of SFI are potentially far reaching. Nationwide, there are more than 130 companies and 10 SFI licensees representing 85% of US paper production and 90% of US industrial timberland that have adopted SFI requirements (Berg and Cantrell 1999). The AF&PA has asked as many as 17 forest product companies not to renew their membership until they comply with the SFI objectives and performance measures. Enforcement and improvement of SFI performance standards continues based on recommendations by an independent panel of experts, and third-party certification has been available since

Received 27 August 2004. Accepted 13 June 2005. Published on the NRC Research Press Web site at <http://cjfr.nrc.ca> on 27 September 2005.

**R. Brown.** Department of Agricultural Economics, University of Kentucky, Lexington, KY 40546, USA.

**D. Zhang.<sup>1</sup>** School of Forestry and Wildlife Sciences, Auburn University, Auburn, AL 36849, USA

<sup>1</sup>Corresponding author (e-mail: [zhangdw@auburn.edu](mailto:zhangdw@auburn.edu)).

2000, but not required, as a part of AF&PA membership. Because SFI certification is only required of AF&PA member companies, nonindustrial private forest (NIPF) landowners and other industry landowners are exempt. Various voluntary certification options (such as the Treasured Forests Program) are available to NIPF landowners as well, but the vast majority of NIPF timberlands are not certified.

During the early design stages of the SFI program, AF&PA timber producers recognized that at some fundamental level any publicly acceptable forest certification program would entail reductions in harvestable timber inventory, defined as the quantity of timber that is commercially harvestable (i.e., stumpage).<sup>2</sup> For example, SFI limits clear-cut sizes and restricts harvests along roadsides for aesthetic reasons. Creation of wildlife corridors and protection of special wildlife habitat contribute to further declines in timber inventories. In most cases, SFI streamside protection requires that fewer trees be harvested than otherwise permissible. Thus, the effect of SFI participation may be characterized as a reduction in aggregate industrial (specifically, SFI-compliant industrial) timber inventories.<sup>3</sup> In the present paper, we trace conceptually and then empirically the impact that this inventory reduction has on the market price and quantity of stumpage supplied to various timber product markets and on consumer and producer welfare in the US South.<sup>4</sup>

## Conceptual model

The present analysis uses the equilibrium displacement model (EDM) approach described by Just et al. (1982), Alston et al. (1995), and Sun and Kinnucan (2001). This approach to applied welfare analysis is applicable to a wide range of problems in natural resource economics and policy (Piggott 1992). For example, Kinnucan and Zhang (2004) used it to measure the incidence of recent US–Canadian trade policies dealing with softwood lumber. The basic EDM measures how equilibrium price and quantity are displaced because of some introduced policy shock such as SFI regulation. The EDM calculations depend on finding reliable elasticity estimates for supply and demand and initial equilibrium price and quantity values. While the sensitivity analysis conducted later in the paper assumes that supply and demand curves are linear within the relevant range near the initial equilibrium and that supply and demand shifts are parallel, the EDM analysis executed here (or elsewhere) does not (Muth 1964). It is this flexibility in modeling supply and demand shocks that makes EDMs particularly useful.

We examine four timber product markets: softwood pulpwood, softwood sawtimber, hardwood pulpwood, and hardwood sawtimber. Assuming that NIPF and government inventories remain unchanged, each timber market can be described by a set of common structural equations (1–6):

$$[1] \quad Q_i = f(P, N) \quad \text{Industry supply}$$

$$[2] \quad Q_{pr} = f(P) \quad \text{NIPF (private) supply}$$

[3]	$Q_s = Q_i + Q_{pr} + Q_g$	Total supply
[4]	$Q_d = f(P)$	Demand
[5]	$Q_s = Q_d$	Equilibrium
[6]	$N = f(C)$	Industrial timer inventory

where there are six endogenous variables

$Q_i$  industry timber quantity supplied;

$P$  stumpage price;

$N$  industry timber inventory;

$Q_{pr}$  NIPF timber quantity supplied;

$Q_s$  aggregate timber quantity supplied;

$Q_d$  aggregate timber quantity demanded;

and two exogenous variables

$C$  environmental certification policy

$Q_g$  government (public) timber quantity

Aggregate timber quantity supplied ( $Q_s$ ) consists of contributions from NIPF ( $Q_{pr}$ ), industry ( $Q_i$ ), and government ( $Q_g$ ) forestlands. Government timberlands generally supply about 5% of all production by volume in the US South, and supply decisions are typically driven by administrative rather than market forces. For this latter reason, timber supplies from public lands are assumed to be unresponsive to market price changes (i.e., supply elasticity = 0). Timber inventories ( $N$ ) are reduced by environmental certification programs ( $C$ ) such as SFI, which in turn reduce industrial timber supplied ( $Q_i$ ). This relationship is illustrated in Fig. 1.

The above system can be expressed equivalently in terms of percent changes and elasticities by first taking the total differential and then dividing both sides of each equation by  $Q_i$ ,  $Q_{pr}$ ,  $Q_s$ , or  $Q_d$  and combining terms.

$$[1'] \quad Q_i^* = \epsilon_i P^* + \xi_i N^*$$

$$[2'] \quad Q_{pr}^* = \epsilon_{pr} P^*$$

$$[3'] \quad Q_s^* = k_i Q_i^* + k_{pr} Q_{pr}^* + k_g Q_g^*$$

$$[4'] \quad Q_d^* = \eta P^*$$

$$[5'] \quad Q_s^* = Q_d^*$$

$$[6'] \quad N^* = m C^*$$

where variables with an asterisk are the relative changes in those variables (e.g.,  $N^*$  equals the original timber inventory minus the reduced inventory due to SFI divided by the original inventory),  $m$  denotes a marginal impact on inventory resulting from a change in the stringency of a certification policy, and  $k_i$ ,  $k_{pr}$  and  $k_g$  are quantity shares. Supply, demand, and inventory elasticities are represented by  $\epsilon$ ,  $\eta$ , and  $\xi$  respectively. Since the functional relationship between  $N$  and  $C$  is not known,  $N^*$  cannot be calculated, but we use a survey to estimate this parameter in this analysis.

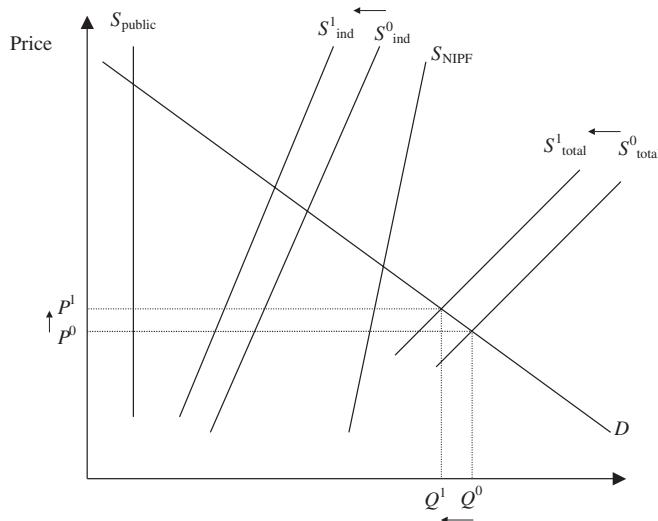
The reduced-form equations for  $P^*$  and  $Q^*$  can be obtained by substituting [6'] into [1'], [1'] and [2'] into [3'], and [3'] and [4'] into [5'], recognizing that  $k_g Q_g^*$  is zero and solving for  $P^*$  and  $Q^*$  to yield

<sup>2</sup>Other timber in geographically inaccessible areas, for example, may be managed for nontimber benefits (e.g., hunting leases) and included in forest inventory, but is not included in timber inventories.

<sup>3</sup>SFI certification may also lead to (i) a price premium; (ii) a long-run increase in timber supply or other nonmarket forest values; (iii) an increase in market share for the forest industry over NIPF landowners. See Conclusions.

<sup>4</sup>Other methods have been used to estimate the welfare impacts of changes associated with timber inventory. See Newman (1990) for example.

**Fig. 1.** Market change due to industry compliance with the Sustainable Forestry Initiative.



$$[7] \quad P^* = \left[ \frac{k_i \xi_i}{(\eta - k_i \epsilon_i - k_{pr} \epsilon_{pr})} \right] N^*$$

$$[8] \quad Q^* = \eta \left[ \frac{k_i \xi_i}{(\eta - k_i \epsilon_i - k_{pr} \epsilon_{pr})} \right] N^*$$

Since some industry producers are not AF&PA members (i.e., are not required to comply with SFI certification),  $k_i$  overstates the proportion of all timberland impacted by SFI. The most appropriate correction requires disaggregating  $k_i$  into those portions of all timberlands that are SFI-compliant industry lands ( $k_{i-c}$ ) and those that are not ( $k_{i-nc}$ ). This change yields

$$[7'] \quad P^* = \left[ \frac{k_{i-c} \xi_i}{(\eta - k_{i-c} \epsilon_i - k_{i-nc} \epsilon_i - k_{pr} \epsilon_{pr})} \right] N^*$$

$$[8'] \quad Q^* = \eta \left[ \frac{k_{i-c} \xi_i}{(\eta - k_{i-c} \epsilon_i - k_{i-nc} \epsilon_i - k_{pr} \epsilon_{pr})} \right] N^*$$

Equations 7' and 8' give the percent changes in initial equilibrium price ( $P^*$ ) and quantity ( $Q^*$ ) given changes in variables on the right-hand side.

Equations 7' and 8' form the basis for the market and welfare analysis that follows. First, elasticity values for the five elasticity variables are gathered from the literature for each timber product. Second, nominal values for  $P$  and  $Q$  along with summary survey estimates for  $N^*$  are presented. Finally, shifts in equilibrium values of  $P$  and  $Q$  are calculated using eqs. 7' and 8', and welfare calculations are performed.

Using  $P^*$ ,  $Q^*$ ,  $P^0$ , and  $Q^0$ , Alston (1991) and Sun and Kinnucan (2001) show that the set of welfare formulas for upward shifts in supply are

$$[9] \quad \Delta PS = P^0 Q^0 (P^* - V_S) (1 + 0.5 Q^*)$$

$$[10] \quad \Delta CS = -P^0 Q^0 P^* (1 + 0.5 Q^*)$$

$$[11] \quad \Delta TS = -P^0 Q^0 V_S (1 + 0.5 Q^*)$$

where  $\Delta PS$ ,  $\Delta CS$ , and  $\Delta TS$  represent changes in producer surplus, consumer surplus, and total surplus, respectively ( $\Delta TS = \Delta PS + \Delta CS$ );  $P^0$  and  $Q^0$  represent initial equilibrium values; and  $V_S$  represents the relative vertical upward shift in supply associated with some exogenous variable (e.g., SFI regulation). As Sun and Kinnucan (2001) show, for upward shifts in supply  $V_S$  is equivalent to  $P^*$  when demand is perfectly inelastic. When demand is not perfectly inelastic, the full vertical shift of that curve ( $V_S$ ) will always be greater than  $P^*$  (assuming an upward shift in supply), incorporating consumer resistance to elevated prices. In the present analysis

$$[12] \quad V_S = \left[ \frac{k_{i-c} \xi_i}{(-k_{i-c} \epsilon_i - k_{i-nc} \epsilon_i - k_{pr} \epsilon_{pr})} \right] N^*$$

Substituting values for  $V_S$ ,  $P^0$ , and  $Q^0$  into eqs. 9, 10, and 11 yields changes in consumer, producer, and total surplus due to compliance with a specific certification scheme (e.g., SFI).

## Empirical analysis

We limit our analysis to the US South for several reasons. The thirteen states that comprise the US South<sup>5</sup> account for the majority of US production of hardwood (50%) and softwood (62%) products by volume (Forest Resource Assessment 2003, Table 39). Secondly, elasticity estimates from the existing literature are relatively more recent and more product specific for the US South than for other parts of the country. Finally, reductions in SFI-compliant industrial timber inventories due to certification would likely be different in the US South than in other geographically different parts of the country such as the Pacific Northwest.

Table 1 reproduces relevant estimates of supply and demand elasticities and of timber supply elasticity with respect to inventory (hereafter referred to as inventory supply elasticity or inventory elasticity) in the US South. The primary observation is that the own-price demand elasticity for timber products is usually quite inelastic. For nonpublic timber, demand elasticity estimates range between -0.03 for North Carolina timber and -0.57 for southern softwood sawtimber. Most own-price timber supply elasticity estimates also tend to be inelastic, although one estimate is 1.20. Industry supply tends to be more elastic (between 0.27 and 1.20) than NIPF supply (between 0.17 and 0.39) for a number of reasons. Newman and Wear (1993), for instance, speculate that NIPF landowners have less elastic supply responses because they receive relatively higher nonmarket benefits from holding timberland, have different expectations regarding future prices, or hold a different opportunity cost of capital.

Inventory (supply) elasticities reveal the responsiveness of harvesting (i.e., timber supply) to changes in overall timber inventories. Under the *ceteris paribus* condition, inventory elasticities are thought to be *a priori* approximately one, as reported by Haynes and Adams (1985). However, stand com-

<sup>5</sup>Includes Alabama, Arkansas, Florida, Georgia, Kentucky, Louisiana, Mississippi, North Carolina, Oklahoma, South Carolina, Tennessee, Texas, and Virginia.

**Table 1.** Summary of stumpage demand, supply, and inventory elasticities.

Source	Region and timber type	Demand	Supply	Inventory
Robinson 1974	Southern pine stumpage	-0.52	0.32	
Adams and Haynes 1980	Forest industry stumpage (SC)		0.47	0.41
	Private stumpage (SC)		0.39	0.66
	Forest industry stumpage (SE)		0.47	0.49
	Private stumpage (SE)		0.3	0.72
Adams et al. 1982	US South			0.57
Haynes and Adams 1985	Forest industry stumpage (SC)		0.63	1
	Private stumpage (SC)		0.17	1
	Forest industry stumpage (SE)		1.2	1.01
	Private stumpage (SE)		0.17	1
Daniels and Hyde 1986	Combined softwood and hardwood in North Carolina	-0.03	0.27	0.16
Newman 1987	Southern softwood pulpwood	-0.43	0.23	1.2
	Southern softwood sawtimber	-0.57	0.55	0.39
Robinson and Fey 1990	Stumpage in the US South	-0.25		
Abt and Kelly 1991	South Georgia and Florida timber	-0.1	0.3–0.4	1.0
Carter 1992	Softwood pulpwood in Texas	-0.41	0.28	0.98
Newman and Wear 1993	Industry sawtimber in SE			0.27
	Industry pulpwood in SE			0.58
	NIPF sawtimber in SE			0.22
	NIPF pulpwood in SE			0.33
Polyakov et al. 2004	Softwood pulpwood in Alabama	-0.77	0.35	
	Hardwood pulpwood in Alabama	-1.72	0.35	

Note: SC, South Central United States; SE, Southeast United States.

**Table 2.** Elasticity estimates used to calculate percent changes in  $P^0$  and  $Q^0$  for timber products.

Factor	Softwood		Hardwood	
	Pulpwood	Sawtimber	Pulpwood	Sawtimber
Demand elasticity ( $\eta$ )	-0.43	-0.57	-0.25	-0.25
Supply elasticity				
Industry ( $\epsilon_i$ )	0.58	0.27	0.58	0.27
NIPF ( $\epsilon_{pr}$ )	0.33	0.22	0.33	0.22
Public ( $\epsilon_p$ )	0	0	0	0
Inventory elasticity ( $\xi_i$ )	1.20	0.39	1.00	1.00

position and substitutions between pulpwood and sawtimber harvesting make inventory elasticities subject to empirical analysis. Pulpwood may be more inventory elastic than sawtimber, since pulpwood has more substitution possibilities.

Table 2 shows the elasticity estimates that we selected for use in our analysis. Ideally, separate elasticity estimates would be available for demand, inventory, and the three timber suppliers (NIPF, industry, and public) for each of four timber products for a total of 20 unique elasticity estimates. Assumptions and simplifications, however, are necessary given incomplete information. Newman (1987) gives demand elasticity estimates for southern softwood pulpwood and softwood sawtimber. No similar estimates for hardwood pulpwood or sawtimber are available; consequently, we use the most recent demand elasticity estimate for southern stumpage (-0.25) for both hardwood products (Robinson and Fey 1990). Newman and Wear (1993) give the most recent supply elasticity estimates for industry and NIPF timberlands. As mentioned earlier, public supply elasticity is assumed to be zero. Newman (1987) offers the most recent inventory elasticities for soft-

wood pulpwood and sawtimber, though similar analyses for hardwood are unavailable. Inventory elasticities for hardwood pulpwood and sawtimber are assumed to be unitary. Later we perform sensitivity analyses to better understand how our choice of elasticity estimates affects consumer and producer welfare.

As noted earlier,  $N^*$  cannot be calculated directly, since the functional relationship between  $N^*$  and  $C$  (i.e., SFI certification) is unknown. Instead, we estimate  $N^*$  using survey data collected in the spring of 2003. Our survey approach was very direct. We simply asked AF&PA (i.e., SFI-compliant) industrial timberland owners to tell us exactly what we needed to know to complete eqs. 7' and 8'; namely how much, as a percentage, their timber inventories have been reduced by SFI compliance (i.e.,  $N^*$ ).

We obtained a list of all 130 AF&PA members and contacted by telephone about 70 member companies thought (or known) to have timberland in the US South. We asked those that owned or controlled such timberland three questions: (i) if and how much timberland do they hold in the US

**Table 3.** Survey estimates of SFI-compliant industrial inventory reductions due to SFI ( $N^*$ ) for different timber products.

Factor	Softwood		Hardwood		All timberland
	Pulpwood	Sawtimber	Pulpwood	Sawtimber	
Mean $N^*$ ( $\times 100$ ), unweighted	-2.64 (4.03)	-2.63 (4.03)	-3.31 (4.04)	-2.75 (4.03)	-2.85 (3.25)
Mean $N^*$ ( $\times 100$ ), weighted	-1.44	-1.60	-2.22	-2.53	-1.85

**Note:** Standard deviations are given in parentheses. The weighted means are always lower than unweighted means, indicating that large industrial timberland owners may be able to alleviate the impact of Sustainable Forestry Initiative (SFI) certification by spreading it to a large timber inventory base. In other words, large companies generally are impacted to a smaller degree by SFI compliance than smaller companies. Since we use a whole-population survey or census approach, the weighted means are a better measure of the SFI impact than the unweighted means, even though our results are biased towards the large landowners.

**Table 4.** Percent changes in price ( $P$ ) and quantity ( $Q$ ) for timber products using reduced-form equations.

Factor	Softwood		Hardwood		
	Pulpwood	Sawtimber	Pulpwood	Sawtimber	
$P^* \times 100$	0.551	0.187	0.647	0.507	
$Q^* \times 100$	-0.237	-0.106	-0.162	-0.127	

South; (ii) the area of timberland contained in each timber class (e.g., softwood pulpwood); and (iii) how much more, as a percentage of current inventories, they could economically (i.e., commercially) harvest if SFI standards were ignored. Our survey strategy was to gather responses from all companies with known holdings of SFI-certified timberland in the US South (i.e., to do a whole-sample survey). However, corporate policy restrictions prohibited several respondents from sharing some data (particularly timber-class data). Ultimately, we collected survey data from 13 firms, covering 89% of all SFI-certified timberland in the US South (R. Cantrell, personal communication, 2005). Eight of these 13 firms provided usable (i.e., complete) data for 76% of all SFI-enrolled timberlands.

Preliminary survey tests showed that ambiguity regarding the proper base period could be avoided if questions about timber inventory reductions were presented in a counterfactual form. That is, respondents were asked to estimate, to the best of their knowledge, how much more timber in each class could be economically harvested if SFI standards were ignored rather than how much SFI compliance had cost in terms of foregone timber inventories. Answers to questions about inventory size and composition were used to weight each AF&PA member's estimate of  $N^*$  using the total number of acres in each class for each company (Table 3). Among all responses, answers to the counterfactual question (i.e., how much more could be harvested if SFI standards were ignored) ranged from 0% to 12% for each timber size class. The weighted average  $N^*$  ranged from -1.44% for softwood pulpwood to -2.53% for hardwood sawtimber.

Using the elasticity estimates from Table 2 and  $N^*$  estimates from Table 3, changes in  $P$  and  $Q$  as a percentage due to SFI compliance were calculated using eqs. 7' and 8'. Results are presented in Table 4.  $P^*$  is positive and  $Q^*$  is negative for each product, reflecting a higher price and lower quantity due to the upward shift in the industry supply curve. Percent changes in  $P$  and  $Q$  tend to be greater for pulpwood than for sawtimber products. This result reflects the fact that, relative to NIPF producers (the dominant non-SFI group),

industry producers (dominated by AF&PA producers) supply a higher fractional share of pulpwood than sawtimber and that inventory elasticities for pulpwood tend to be higher. Both of these factors increase the numerator of eqs. 7' and 8', leading to a higher estimate for  $P^*$  and  $Q^*$ .

Using estimates of  $P^*$  and  $Q^*$  from Table 4 and initial equilibrium values for price ( $P^0$ ) and quantity ( $Q^0$ ), values for the displaced price ( $P^1$ ) and quantity ( $Q^1$ ) can be calculated (Table 5). As expected, displaced prices are higher and displaced aggregate quantities are lower because of the upward shift of the supply curve due to SFI compliance. However, quantity changes are different for public, NIPF, and both industrial producers (SFI certified and noncertified). NIPF and non-SFI-compliant industrial landowners (both of which are exempt from SFI compliance) increase the quantity of timber they supply as market prices increase. Decreases in SFI industry supply are found by subtracting the NIPF and non-SFI industry quantity responses from the total shift in output quantity and by recalling that public supply is assumed to be constant.

## Results

Total surplus (TS) is reduced by about \$35.5 million, of which consumers lose about \$11.9 million in consumer surplus (or 34% of the TS loss) annually due to higher timber prices. Timber producers as a group lose \$23.6 million in producer surplus (66% of TS loss) as a result of SFI compliance. However, among these producers, SFI compliance costs are not borne equally. Producer surplus (PS) changes for NIPF, non-SFI industry, and public suppliers are positive, since these three producers are not required to comply with SFI standards but still benefit from rising market prices. Since the change in total PS ( $PS_{total}$ ) is negative, this implies that SFI compliant industry producers as a group face PS losses in excess of  $\Delta PS_{total}$  (i.e.,  $\Delta PS_{total} = \Delta PS_{i-c} + \Delta PS_{i-nc} + \Delta PS_{pr} + \Delta PS_g$ ). Gains in PS for public suppliers equal the change in market price (due to SFI compliance by industry suppliers) times  $Q_g$ , since the public supply elasticity ( $\epsilon_g$ ) is assumed to be zero ( $PS_g = (P^1 - P^0)Q_g^0$ ). For NIPF and non-SFI industry suppliers, PS is equal to the change in market price times the average output quantity before and after SFI (i.e.,  $PS_{pr} = 0.5(P^1 - P^0)(Q_{pr}^0 + Q_{pr}^1)$  and  $PS_{i-nc} = 0.5(P^1 - P^0)(Q_{i-nc}^0 + Q_{i-nc}^1)$ , respectively). Finally, assuming  $PS_{total} = PS_{i-c} + PS_{i-nc} + PS_{pr} + PS_g$ , then  $PS_{i-c} = PS_{total} - PS_g - PS_{pr} - PS_{i-nc}$ .

Calculated in this way, SFI compliance shifts about \$9.7 million annually in PS from SFI industry producers to NIPF, public, and non-SFI industry producers. The total PS loss to

**Table 5.** Initial and displaced equilibrium values for  $P$  and  $Q$  for four timber products (2002).

Factor	Softwood		Hardwood	
	Pulpwood	Sawtimber	Pulpwood	Sawtimber
Initial price ( $P^0$ )	6.06	36.49	5.00	18.88
Initial quantity ( $Q^0$ )				
NIPF	7708	64 899	5963	35 379
Industry: SFI	3433	24 511	1526	4058
Industry: non-SFI	1144	8171	509	1353
Public	674	5705	359	3179
Total	12 959	103 286	8357	43 969
Displaced price ( $P^1$ )	6.09	36.56	5.03	18.98
Displaced quantity ( $Q^1$ )				
NIPF	7722	64 926	5976	35 418
Industry: SFI	3384	24 371	1497	3961
Industry: non-SFI	1148	8175	510	1355
Public	674	5705	359	3179
Total	12 928	103 176	8342	43 913

**Note:** Prices in dollars per ton (1 short ton = 0.9072 metric t) and quantities in thousands of tons. Initial  $P$  values from Timber-Mart South (average for 2002); initial  $Q$  values from USDA Forest Service (2002) Timber Products Output Mapmaker. Sustainable Forestry Initiative (SFI) (and non-SFI) industry output quantity based on share of all industry-owned timberland acres in the US South enrolled (and not enrolled) in the SFI program. Nationwide, 90% of industry-owned land is SFI certified (Berg and Cantrell 1999); in the US South, this figure drops to 75% (Cantrell 2005). Totals may be different than the sum of their constituent parts because of rounding. NIPF, nonindustrial private forest.

**Table 6.** Changes in producer, consumer, and total surplus (in millions of US dollars).

Surplus	Softwood		Hardwood		All wood products
	Pulpwood	Sawtimber	Pulpwood	Sawtimber	
Consumer surplus	-0.4	-7.0	-0.3	-4.2	-11.9
Producer surplus					
NIPF	0.3	4.4	0.2	3.4	8.3
Industry: SFI	-0.8	-23.3	-0.4	-8.8	-33.3
Industry: non-SFI	0.0	0.6	0.0	0.1	0.7
Public	0.0	0.4	0.0	0.3	0.7
Total	-0.5	-17.9	-0.2	-5.0	-23.6
Total surplus	-0.9	-24.9	-0.4	-9.2	-35.5

**Note:** Totals may be different than sum of constituent parts because of rounding. NIPF, nonindustrial private forest; SFI, Sustainable Forestry Initiative.

SFI industry producers is nearly \$33.3 million annually (Table 6).

Those NIPF, public, and non-SFI industry landowners with inventories consisting primarily of mature trees, in particular softwood, benefit most, as sawtimber constitutes the overwhelming majority (95%) of the non-SFI producer surplus increase. Softwood sawtimber constitutes about 54% and hardwood sawtimber about 41% of non-SFI producer surplus gains. By contrast, SFI industrial lands dominated by softwood sawtimber account for the majority (69%) of PS losses due to SFI compliance, with hardwood sawtimber making up the most of the balance (27%). While the average percent change in industrial pulpwood inventories ( $N^* = -1.83$ ) is comparable to that of sawtimber ( $N^* = -2.06$ ), the former had relatively little impact on surplus changes for either SFI industry producers (4%) or non-SFI producers (5%).

We performed a sensitivity analysis on all elements of the equilibrium displacement model (EDM) analysis where uncertainty in selection of estimated parameters exists. The ini-

tial equilibrium values for price ( $P^0$ ) and quantity ( $Q^0$ ) are not subjected to sensitivity analysis, since these parameters are observed directly and are well known. What is uncertain, as evinced by the variation in values in Table 1, are the true values of the elasticities ( $\eta, \epsilon_i, \epsilon_{pr}, \xi_i$ ) and the supply shift ( $N^*$ ) for each timber product. Sensitivity analyses on these parameters are generally done in two ways. One is to do a stochastic simulation as in Sun and Kinnucan (2001). The other is to raise and lower the parameters by some fixed amount (e.g., 50%) around their baseline or “best-bet” values. An advantage of the former is that 95% confidence intervals can be placed around welfare estimates. An advantage of the latter is that one can see how assumptions about supply and demand elasticities affect the incidence of the supply shift. We follow the latter approach.

The sensitivity of consumer and producer surplus to changes in either  $N^*$  or  $\xi_i$  is exactly proportional to changes in either of these parameters. For example, if the percent change in softwood pulpwood inventories due to SFI regulation ( $N^*$ ) is

**Table 7.** Sensitivity analysis of consumer and producer surplus estimates (in millions of US dollars) at product level.

Product type	Surplus type	Producer type	Supply					
			Demand		NIPF		Industry	
			More	Less	More	Less	More	Less
<b>Softwood</b>								
Pulpwood	Consumer	—	-0.3	-0.6	-0.4	-0.5	-0.4	-0.5
		NIPF	0.2	0.3	0.2	0.3	0.2	0.3
		Ind: SFI	-0.8	-0.7	-0.6	-1.1	-0.6	-1.1
		Ind: non-SFI	0	0.1	0	0	0	0
	Producer	Public	0	0	0	0	0	0
Sawtimber	Consumer	—	-5.2	-11.0	-6.5	-7.7	-6.7	-7.4
		NIPF	3.3	6.9	4.1	4.8	4.2	4.7
		Ind: SFI	-23.7	-22.3	-17.5	-34.3	-19.4	-29.1
		Ind: non-SFI	0.4	0.9	0.5	0.6	0.5	0.6
	Producer	Public	0.3	0.6	0.4	0.4	0.4	0.4
<b>Hardwood</b>								
Pulpwood	Consumer	—	-0.2	-0.3	-0.2	-0.3	-0.2	-0.3
		NIPF	0.2	0.2	0.2	0.2	0.2	0.2
		Ind: SFI	-0.4	-0.4	-0.3	-0.6	-0.3	-0.5
		Ind: non-SFI	0	0	0	0	0	0
	Producer	Public	0	0	0	0	0	0
Sawtimber	Consumer	—	-3.3	-5.8	-3.5	-5.2	-4.1	-4.4
		NIPF	2.7	4.7	2.8	4.2	3.3	3.5
		Ind: SFI	-8.9	-8.7	-6.2	-15.4	-8.2	-9.6
		Ind: non-SFI	0.1	0.2	0.1	0.2	1.1	0.1
	Producer	Public	0.2	0.4	0.3	0.4	0.3	0.3

**Note:** Calculations of surplus changes assume that single elasticity estimates are varied by 50% from values listed in Table 2 and that all other elasticity estimates are held constant. Totals may be different than sum of constituent parts because of rounding. NIPF, nonindustrial private forest; SFI, Sustainable Forestry Initiative.

**Table 8.** Sensitivity analysis results of consumer, producer, and total surplus estimates (in millions of US dollars) for all wood products combined.

Varied elasticity	Surplus type	Producer						Total
		Consumer	Public	NIPF	Industry	non-SFI	Industry SFI	
<b>Demand</b>								
More elastic	-9.0	0.6	6.3	0.6			-33.8	-35.5
Less elastic	-17.7	1.1	12.1	1.1			-32.2	-35.5
<b>NIPF supply</b>								
More elastic	-10.6	0.6	7.3	0.7			-24.6	-26.6
Less elastic	-13.6	0.8	9.6	0.8			-51.4	-53.8
<b>Industry supply</b>								
More elastic	-11.4	0.7	7.9	0.7			-28.5	-30.6
Less elastic	-12.6	0.8	8.7	0.8			-40.2	-42.6

**Note:** Calculations of surplus changes assume that single elasticity estimates are varied by 50% from values listed in Table 2 and that all other elasticity estimates are held constant. Totals may be different than sum of constituent parts because of rounding. NIPF, nonindustrial private forest; SFI, Sustainable Forestry Initiative.

actually 50% less for that product than that reported by survey respondents (-0.72% instead of -1.44%), all surplus change calculations for softwood pulpwood are reduced by 50%. Using this logic, losses in total surplus can be shown to be between \$17.8 and \$53.3 million annually given negative or positive 50% changes in either  $N^*$  or  $\xi_i$ .

Unlike  $\xi_i$ , the other three elasticity estimates ( $\eta$ ,  $\epsilon_i$ , and  $\epsilon_{pr}$ ) when varied change the incidence borne by consumers and

producers disproportionately. Each of these three elasticity measures are increased and decreased by 50%. Product-level calculation results are presented in Table 7 and aggregate results are presented in Table 8. These calculations show that, as expected, the change in total surplus (\$35.5 million) is invariant to changes in demand elasticities and that consumer and producer surpluses are sensitive to changes in this parameter. However, eq. 12 shows that, holding all other parameters

constant,  $V_s$  changes in response to changes in  $\epsilon_i$  or  $\epsilon_{pr}$ . In other words, holding all other parameters constant and changing either  $\epsilon_i$  or  $\epsilon_{pr}$  will yield a different  $V_s$  and consequently changes in total surplus. Table 8 indicates that, for exogenous errors in  $\eta$ ,  $\epsilon_i$ , or  $\epsilon_{pr}$ , the welfare costs of SFI compliance range between \$24.6 and \$51.4 million annually for SFI-compliant industry producers and between \$9.0 and \$13.7 million annually for consumers. Estimated annual NIPF, public, and non-SFI industry gains range between \$6.3 and \$12.1 million, \$0.6 and \$1.1 million, and \$0.6 and \$1.1 million, respectively.

## Conclusions

The results obtained from the EDM analysis quantify the market-based economic impacts of SFI compliance on the economy of the US South and on industrial and nonindustrial timber producers specifically. We show that SFI compliance by AF&PA (i.e., SFI-compliant) industrial timberland companies in the US South costs these firms collectively about \$33.8 million annually in lost producer surplus and has benefited non-SFI (i.e., NIPF, public, and non-SFI industry) producers collectively about \$9.7 million through higher market prices. Other costs, such as SFI administrative costs, may be substantial but are not reflected in the partial equilibrium analysis executed here. Also ignored are regional impacts beyond the US South, which deserve further consideration.

While our analysis shows that SFI compliance in the US South annually costs society nearly \$36 million in the aggregate, this sum is relatively small compared to the nearly \$4.7 billion timber market in the US South. The equilibrium price changes due to SFI compliance are very small: about 3 cents for pulpwood and about 7–10 cents for sawtimber. These price changes are well within the error of reporting and represent essentially no market impact. Examination of the welfare impacts on a per-acre basis reinforces this conclusion. SFI industry producers face an annual surplus loss of \$1.24/acre (1 acre = 0.4047 ha), while NIPF and non-SFI industry producers annually gain \$0.05/acre and \$0.08/acre, respectively.<sup>6</sup> The “free-rider” benefits enjoyed by NIPF and non-SFI-compliant industrial timberland owners are small. Nonetheless, AF&PA industrial timberland owners must strive through market forces to recoup welfare losses (however small) that result from timber inventory reductions and SFI implementation. Without a price premium and increased market share for SFI-certified forest products, the SFI-compliant industrial landowners incur net losses.

The present analysis also demonstrates how survey data may be used to estimate missing parameter values in an equilibrium displacement model (EDM). Our analysis is perhaps the first to couple these two research techniques in the forestry literature. When, as in the present case, one or more of these estimates is either unavailable or cannot be calculated, the present analysis shows how to proceed with the EDM approach using supplemental surveys.

We have not considered that SFI certification may also lead to (i) a price premium; (ii) a long-run increase in timber supply (e.g., due to different harvesting techniques) or other

nonmarket forest values; and (iii) an increase in market share for SFI (vis-à-vis non-SFI) producers. These dynamics seem appropriate for future study. Finally, there is a great need for updated elasticity estimates for various timber products in distinct geographic regions in the forest economics profession.

## Acknowledgements

The authors wish to thank Henry Kinnucan, Henry Thompson, and John Jackson for their comments and The Center for Forest Sustainability at Auburn University for financial support.

## References

- Abt, R.C., and Kelly, D. 1991. Pine supply, demand, and inventory in South Georgia and Florida. Final report, University of Florida, Gainesville, Fla.
- Adams, D.M., and Haynes, R.W. 1980. The 1980 softwood timber assessment market model: structure, projections, and policy simulations. *For. Sci. Monogr.* **22**: 1–64.
- Adams, D.M., Haynes, R.W., Dutrow, G.F., Barber, R.L., and Vasievech, J.M. 1982. Private investment in forest management and the long-term supply of timber. *Am. J. Agric. Econ.* **64**: 232–241.
- Alston, J.M. 1991. Research benefits in a multi-market settings: a review. *Rev. Marketing Agric. Econ.* **59**: 23–52.
- Alston, J.M., Norton, G.W., and Pardey, P.G. 1995. Science under scarcity: principles and practice for agricultural research evaluation and priority setting. Cornell University Press, Ithaca, N.Y.
- Berg, S., and Cantrell, R. 1999. Sustainable forestry initiative: toward a higher standard. *J. For.* **97**: 33–36.
- Carter, D.R. 1992. Effects of supply and demand determinants of pulpwood stumpage quantity and price in Texas. *For. Sci.* **38**: 652–660.
- Daniels, B.J., and Hyde, W.F. 1986. Estimation of supply and demand for North Carolina's timber. *For. Ecol. Manage.* **14**: 59–67.
- Forest Resource Assessment. 2003. Renewable Resources Planning Act (RPA). Available from <http://www.ncrs.fs.fed.us/4801/national-programs/rpa/> [accessed 18 August 2003].
- Haynes, R.W., and Adams, D.M. 1985. Simulations of the effects of alternative assumptions on demand-supply determinants on the timber situation in the United States. USDA Forest Service, Forest Resource and Economics Research, Washington, D.C.
- Just, R.E., Hueth, D.L., and Schmitz, A. 1982. Applied welfare economics and public policy. Prentice-Hall Inc., Englewood Cliffs, N.J.
- Kinnucan, H., and Zhang, D. 2004. Incidence of the 1996 Canada–U.S. softwood lumber agreement and the optimal export tax. *Can. J. Agric. Econ.* **51**: 73–88.
- Muth, R.F. 1964. The derived demand curve for a productive factor and the industry supply curve. *Oxf. Econ. Pap.* **16**: 221–234.
- Newman, D.H. 1987. An econometric analysis of the southern softwood stumpage market: 1950–1980. *For. Sci.* **33**: 932–945.
- Newman, D.H. 1990. Shifting southern softwood stumpage supply: implications for welfare estimation from technical change. *For. Sci.* **36**: 705–718.

<sup>6</sup> Assumes SFI industrial, non-SFI industrial, and NIPF forestland in the US South comprises 26.9 million, 9.0 million, and 152.9 million acres, respectively (Forest Resource Assessment 2002, Table 2; Cantrell 2005).

- Newman, D.H., and Wear, D.N. 1993. Production economics of private forestry: a comparison of industrial and nonindustrial forest owners. *Am. J. Agric. Econ.* **75**: 674–684.
- Piggott, R.R. 1992. Some old truths revisited. *Aust. J. Agric. Econ.* **36**: 117–140.
- Polyakov, M., Teeter, L., and Jackson, J.D. 2004. Econometric analysis of Alabama's pulpwood market. *For. Prod. J.* **55**: 4–14.
- Robinson, V.L. 1974. An econometric model of softwood lumber and stumpage markets, 1947–1967. *For. Sci.* **20**: 171–179.
- Robinson, V.L., and Fey, W.R. 1990. Future timber demand, an alternative model. *South. J. Appl. For.* **14**: 177–183.
- Stevens, J., Ahmad, M., and Ruddell, S. 1998. Forest products certification: a survey of manufacturers. *For. Prod. J.* **48**: 43–49.
- Sun, C., and Kinnucan, H.W. 2001. Economic impact of environmental regulations on southern softwood stumpage markets: a reappraisal. *South J. Appl. For.* **25**: 108–115.
- Timber-Mart South. 2002. Market Newsletter 6, No. 1–4. Center for Forest Business, University of Georgia, Athens, Ga.
- USDA Forest Service. 2003. Timber Products Output Mapmaker, version 1.0 [computer program]. Available from [http://ncrs2.fs.fed.us/4801/fiadb/rpa\\_tpo/wc\\_rpa\\_tpo.asp](http://ncrs2.fs.fed.us/4801/fiadb/rpa_tpo/wc_rpa_tpo.asp) [accessed 5 January 2003].