ANALYSIS

Estimating price compensation requirements for eco-certified forestry

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Abstract

Eco-certified forestry (ECF) is defined as forest management that incorporates ecological concerns into commercial timber production. In this paper, we link the adoption of ECF practices to shifts in the timber supply function. We use a spatially disaggregated model of southeastern US timber supply to simulate the empirical relationship between variations in the price premium offered for timber produced under ECF regimes and producer surplus-maximizing rates of ECF. The simulation results suggest that a large share of nonindustrial private timber suppliers in the region may have relatively small compensation requirements, but complete adoption by the sector would require a large premium. © 2001 Elsevier Science Ireland Ltd. All rights reserved.

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1. Introduction and background

Concern over a global decline in the abundance and ecological integrity of forested ecosystems led to the establishment of sustainable forest management (SFM) principles at the 1992 UNCED conference in Rio de Janeiro. Countries throughout the world are now undertaking efforts to abide by the SFM principles and to devise plans to achieve forest sustainability in the near future.

Concurrent with the growing concern over the world’s forests has been the increased use of market-based incentives for environmental protection. While market incentives have traditionally been viewed as an instrument at the government’s disposal (e.g., tradable permits and externality taxes), nongovernmental entities have entered the arena with the use of eco-labels for environmentally friendly production practices. Together these trends provide the foundation for a system of forest certification, wherein timber producers voluntarily adopt a management regime that a third party deems is ecologically sound and respectful.
of local cultures. The underlying premise is that when forest practices become an observable attribute of the final product consumers can act on their preferences for products deemed more sustainable in their production methods. This creates market demand for certified products and, by extension, for sustainable forest practices.

The paper focuses on the ecological (rather than cultural) aspects of certification and associates forest certification with the adoption of ‘eco-certified forestry’ (ECF) because, as difficult as it may be to model certain ecological interactions with the forest production process, modeling the effects of cultural factors such as respect for indigenous populations and local community stability would be virtually impossible. Therefore, this paper does not seek to model the effects of forest certification, per se, rather it models the adoption of forest practices tied to certification’s ecological objectives.

The paper provides a brief background on the history and objectives of forest certification. It then describes a conceptual model of timber supply, focusing on the effect that a change in supply conditions, such as those imposed by ECF, can have on output decisions and producer welfare, both within a single period and over time. The model produces a measure of the compensation required to adopt ECF. The modeling framework is applied to data from the southeast US to examine the potential effect of ECF standards on compensation requirements for categories of private timber suppliers there.

1.1. Global criteria and regional standards

The dominant third-party certification program throughout the world operates under the auspices of the Forest Stewardship Council (FSC). The FSC is an independent, nonprofit organization based in Oaxaca, Mexico, that was founded in 1993 by a consortium of parties ranging from environmental organizations to timber companies. The FSC’s main function is to serve as an international accrediting organization for certifiers — those parties that actually verify compliance with FSC standards.

This standards-setting process is tied directly to the SFM principles established at the 1992 UNCED Conference in Rio de Janeiro (Elliott and Donovan, 1996). The FSC is seeking to establish internationally recognized principles and criteria of forest management as a basis for accrediting regional certifiers. From this set of principles, regional groups develop standards suitable to the region’s ecology, economy, and social conditions. The FSC principles serve as general guidelines for SFM, but the actual guidelines for on-ground forest management are developed at the regional level by different groups in collaboration with stakeholders.

Our analysis draws from the development of FSC certification standards for the southeastern US. Standards have been developed after consultation with stakeholder groups through a series of public meetings and the subsequent formation of a workgroup that is refining the standards subject to public feedback. Our approach is to model the effects of those general features that relate to activities such as the conversion of natural forests to plantations, the intensity of plantation manage-

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1 Different types of certification are distinguished by the party verifying the action. Under first-party certification, the entity itself declares that it meets certification standards. Under second-party certification, an organization to which the entity belongs (e.g. a professional or trade organization) verifies compliance. When an independent organization having no affiliation with the entity(ies) seeking certification verifies compliance, this is referred to as third-party certification. Third-party certification is the primary focus of this paper.

2 In this paper we focus solely on the compensation requirements of suppliers. A more general equilibrium system might take this several steps further and solve for equilibrium between the certified and noncertified markets on both the supply side and the demand side. But that would require a detailed specification of certified and noncertified consumers and an empirical characterization of their choices at different price premia, which is beyond the scope of this paper.

3 Standards development in the southeastern US is a cooperative effort between the FSC; the Forest Management Trust of Gainesville, FL; and Tall Timbers Research of Tallahassee, FL. As of this writing, the standards are in final draft form (Southeastern Regional Forest Certification Standards Project [SRFCSP] 1999), awaiting approval from the international body of the FSC. Although the standards may change upon final review, it seems unlikely that they will substantially deviate from the main features described here.
1.2. Previous research

Economic studies of certification have focused primarily on the demand side, particularly regarding consumers’ willingness to pay (WTP) premia for certified products (Winterhalter and Cassens, 1993; Ozanne and Vlosky, 1997; Stevens et al., 1997; Vlosky and Ozanne, 1997). These studies have all employed survey methods and find a wide range of sometimes conflicting evidence on the portion of consumers who are willing to pay any premium at all for certified products (the size of the market), 3–70%, and the average size of the WTP premium held by certified product consumers, 0–20%.

Analysis of certification’s supply-side issues have been either descriptive (Baharuddin, 1995; Simula, 1996; Kiker and Putz, 1997) or theoretical (Murray and Casey, 1998; Swallow and Sedjo, 2000), but no rigorous empirical examination has been performed to gauge the potential size and distribution of certification impacts on timber supply. This paper addresses that gap in the literature by empirically analyzing potential certification impacts on timber suppliers in the southeastern US.

2. Conceptual model

The certification decision is cast here as a choice between adopting ECF or continuing with the status quo forest management regime. We assume that the forest manager is endowed with a forest asset of specific size, quality, species, and age class characteristics and selects a regime that maximizes the value of the forest enterprise. The limits to optimization are the initial allocation of forest assets and the technology of forest production. We begin this section by defining the regime in terms of its key decision variables and its corresponding monetary value. We then identify how ECF constraints affect supply conditions and how this translates into a measure of compensation (price premium) required to maintain welfare equivalence between an ECF regime and the status quo.

2.1. Forest management regime

A regime is defined here as the specific plan for managing a forest property from the present time onward. The plan involves both a schedule for harvesting timber from evolving inventories and a schedule for investing in inventory development. We proceed by specifying single-period harvest and investment equations, respectively. Then, we aggregate these levels over time to express their effect on the forest asset value, the monetary return to a particular forest regime for a given area of forestland.4

2.1.1. Single-period timber supply

At any point in time, a manager decides how much timber to harvest based on his current endowment of timber and a variety of factors that determine how much of the endowment to harvest and how much to leave for the future. Year t harvest quantities are thereby determined by the short-run (fixed inventory) supply function:5

\[ Q_t = Q(P_t, I_t, h_t, v) \] (1)

where \( P_t \) is the price of timber, \( I_t \) is the forest inventory endowment, \( h_t \) is the price of variable inputs directly associated with harvesting, and \( v \) is a vector of fixed characteristics of the landowner that affect the propensity to harvest timber. The \( v \) factors might include the landowner’s marginal rate of time preference (discount rate) and factors indicating relative preference for timber and non-timber outputs. We assume the marginal opportunity cost function is increasing in output; there-

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4 The term ‘management regime’ has a very active connotation, but it is also meant to capture passive management where the owner/manager explicitly or implicitly decides to forego silvicultural interventions, harvests, and the like. One reviewer has suggested that these owners might not respond to rational incentives, but we see no reason to conclude that such landowners are in any way acting irrationally. Rather we assert they are making rational choices to emphasize non-timber forest outputs over timber to satisfy their own preferences.

Therefore, the harvest supply function is upward-sloping \([\partial Q_t^s/\partial P_t > 0]\). All else equal, output increases with the level of merchantable inventory available for harvesting \([\partial Q_t^s/\partial I_t > 0]\). Output is assumed to correspond negatively with a change in harvesting costs \([\partial Q_t^s/\partial h_t < 0]\). These partial effects are confirmed by empirical analysis of timber supply (Adams and Haynes, 1980, 1996; Newman, 1987; Newman and Wear, 1993).

Producer surplus represents the gross timber profits (quasi-rents) accruing to the forest enterprise in period \(t\). Producer surplus can be expressed as the integral of the supply function over price:

\[
PS_t = \int_0^{P_t} Q_t^s(\rho|I_t,h_t)\,d\rho.
\]  

where \(\rho\) indexes variation of the timber price from zero to the observed market price, \(P_t\). The \(PS_t\) measure can be viewed as period \(t\)’s return to fixed factors, which are the forest inventory, \(I_t\), and (implicitly) the land on which the inventory is located.

2.1.2. Multiperiod activity

In forestry, inputs such as regeneration and timber stand improvement can be viewed as investments in future forest stock, which affect future production possibilities. Present management inputs affect future production possibilities by accumulating forest growing-stock inventory. Inventory evolves according to the following relation:

\[
I_t = I_{t-1} + G(I_{t-1},X_{t-1},X_{t-2},...) - Q_t.
\]  

\(I_t\) is year \(t\) timber inventory volume, \(G(\cdot)\) represents inventory growth as a function of the previous year’s inventory and all previous investment inputs \((X_{t-1},X_{t-2},...)\), and \(Q_t\) is the amount of the inventory that is harvested in year \(t\).

The optimal level of investment in year \(t\) \((X^*_t)\) equates the marginal effect of the investment on the present value of all future quasi-rents with the unit price of the investment, \(w_t\):

\[
\int_t^\infty \left( \frac{\partial PS_m^*}{\partial I_m} \right) \left( \frac{\partial I_m}{\partial X^*_t} \right) e^{-rt} \, dm = w_t
\]  

where \(m\) indexes time from the current year \(t\) onward.

2.1.3. Forest asset value

Subject to the equation system (1)–(4), a forest enterprise endowed with an initial inventory \((I_0)\) and landowner characteristics \((v)\), facing exogenous price schedules over time \((P_0, P_1, ...)\) and \((w_0, w_1, ...)\), unconstrained by factors such as ECF restrictions, will generate a schedule of outputs \((Q^*_0, Q^*_1, ...)\), inventory investment levels \((X^*_0, X^*_1, ...)\), the corresponding inventory path \((I^*_0, I^*_1, ...)\), and a stream of quasi-rents \((PS^*_0, PS^*_1, ...)\). The monetary value associated with this regime \((V^*)\) is the present value of the quasi-rents less the costs of the inventory investments

\[
V^* = \int_0^\infty [PS^*_t - w_t X^*_t] \, e^{-rt} \, dt
\]

2.2. ECF regime and the compensating price premium

Let \(X^*\) indicate the time vector of forest investment inputs defining the forest enterprise’s baseline management regime (i.e., that which they select without the option to adopt ECF practices and obtain certification). We define the forest certification regime by the vector of “allowable” inputs, \(X^C\), which are exogenously determined by the ECF standards. We assert that \(X^C \leq X^*\) (i.e., ECF (weakly) constrains the application of investment inputs). In this regard, ECF can be viewed as either less or equally input-intensive as the baseline management regime. As described in more detail below, certification constraints prescribe limits to the amount of artificial regeneration of plantations, the amount of inventory that can be managed for timber production, and the application of chemical inputs.

A critical issue is determining the threshold price premium at which the forest enterprise is indifferent between operating under an ECF regime and receiving the premium and operating with the status quo regime and receiving the

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6 Harvesting costs are traditionally subtracted from delivered timber prices to derive the stumpage price paid to forest owners. Thus, Eq. (1) is often specified without the harvest cost term but with the price term explicitly defined as a stumpage price. In either specification, a rise in harvest input prices would lead to a reduction in harvested output.
baseline time vector of prices, \( P \). The compensating price premium (CPP) is defined as the value, \( \tau^{CT} \), that equates asset values for the two regimes:

\[
V^C[P(1 + \tau^{CT})|X^C] = V^*_P(P).
\]  

(6)

Combining Eqs. (Eq. (5)) and (Eq. (6)) shows that the CPP is the value of \( \tau^{CT} \) that equates the present value of quasi-rents under the ECF regime with the present value of quasi-rents under the baseline regime, adjusted for the difference in investment costs between regimes:

\[
\int_{0}^{\infty} [PS^C_t[P_r(1 + \tau^{CT})]e^{-\eta t}] \, dt
\]

\[
= \int_{0}^{\infty} PS^*_P[P_r]e^{-\eta t} \, dt + \int_{0}^{\infty} w_r(X^C_t - X^*_t)e^{-\eta t} \, dt
\]

(7)

First, we note that if ECF constraints are not binding, certified values will be the same as baseline values and the CPP threshold will be \( \tau^{CT} = 0 \). But if ECF is binding, it shifts inwards the timber supply function and thereby reduces producer surplus if the price is unchanged. Under this situation, a positive price markup (i.e., premium) would be necessary to equate producer surplus values across regimes. However, the investment cost term in Eq. (7) will be negative under binding input constraints \( (X^C < X^*) \) and will at least partially offset the positive premium requirement. This raises the question of whether the net CPP could ever be negative (i.e. a landowner would be willing to accept a price reduction to operate under ECF). A negative CPP implies that the investment cost savings from reduced input intensity exceeds the corresponding loss in quasi-rents at the baseline price vector. This is tantamount to the notion that the investments foregone by adopting an ECF regime are uneconomic in the first place. While there are, no doubt, forest landowners who make uneconomic investments, we presume that this is an ex post realization rather than an ex ante plan. Thus, the CPP must be nonnegative to be consistent with the baseline rational behavior we assume in our model.7

2.2.1. Finite time horizons, ending inventories, and option value

The CPP computation above is based on an infinite horizon forest asset valuation model. However, to simulate an ECF decision, it is best to truncate the time horizon to a finite period. This is both for practical purposes — empirical projection models can only operate under finite horizons — and for conceptual reasons — the ECF decision is not irreversible. Forest-sector models typically address this situation by valuing the inventory at the end of the time horizon, period \( T \). Under the baseline regime, the forest asset value is modified by adding an ending inventory value, the second value in the following equation:

\[
V^* = \int_{0}^{T} [PS^*_P - w_r X^*_t]e^{-\eta t} \, dt + [P_T I^*_t]e^{-rT}
\]

(8)

Therefore, an adjustment to the CPP calculation is necessary to account for differences in the value of the forest asset at the end of \( T \) years. The threshold condition then captures differences in quasi-rents, costs, and ending inventories.

\[
\int_{0}^{T} [PS^C_t[P_r(1 + \tau^{CT})]e^{-\eta t}] \, dt
\]

\[
= \int_{0}^{T} PS^*_P[P_r]e^{-\eta t} \, dt + \int_{0}^{T} w_r(X^C_t - X^*_t)e^{-\eta t} \, dt
\]

\[
- P_T(I^*_t - I^*_T)e^{-rT}
\]

(9)

The difference in ending inventories here is valued at the noncertified price, which reflects the notion that ECF is not irreversible. What we are simulating here is a situation in which the landowner essentially commits to ECF for \( T \) years and can then re-evaluate. The value of the forest inventory at the end of \( T \) years can be viewed as an option value, without necessarily being restricted to ECF management beyond year \( T \). At minimum, the inventory’s option value equals its liquidation value in the traditional noncertified timber market — timber harvests from liquidation presumably could not be sold in a certified market. Thus if ECF causes inventories to rise, \( (I^*_T > I^*_T) \), for example, because of less-intensive harvesting, this raises the ending inventory option value and thereby diminishes the CPP require-

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7Our empirical results below bear this out. In no cases is CPP negative once we adjust for investment cost savings and ending inventory effects.
ment. In essence, inventory accumulation is a form of compensation that counters the CPP requirements computed thus far. If, however, ending inventories are lower in the ECF regime, for instance due to less-intensive silviculture, option values are foregone and additional compensation will be required to pursue the regime.

2.3. ECF compensation function

Imagine an auctioneer offering successive price premia, \( \tau^C \), for timber suppliers if they sell in the certified market. A supplier will choose to enter the market (adopt ECF and certify) at a price premium that exceeds that supplier’s threshold premium \( [\tau^C > \tau^{CT}] \). The CPP measures the relative strength of the market signal necessary to induce voluntary adoption of the certified regime. Timber markets are typically populated by a heterogeneous mix of timber suppliers with widely varying forest endowments and differing objectives. The result is a forested landscape where a broad range of management intensity is observed. Thus, there is likely to be a spectrum of CPP values distributed across the timber market. There will be low-intensity suppliers for whom the ECF constraints will be minimally binding and may require little, if any, compensation to adopt. And there will be high-intensity suppliers for whom the constraints may be heavily binding and cause greater compensation requirements. The heterogeneity in CPPs lies at the heart of constructing an upward-sloping compensation function across the universe of potential suppliers. This is illustrated for a hypothetical timber market in Fig. 1. The vertical axis represents the percentage price premium offered in the certified market and the horizontal axis represents the magnitude of timber supply capacity (timberland) for which the corresponding price premium exceeds the compensation requirement.

3. ECF policy simulations

The ultimate product of the empirical analysis is an estimated ECF compensation function for the southeastern US region.\(^8\) Empirical characterization of these functions provides ex ante evidence of the potential size and distribution of market incentives necessary to induce ECF. The conceptual model indicates four main tasks to estimate an ECF compensation function for the region:

- establish baseline (non-ECF) vector of prices, outputs, investment input intensity, and inventories for representative supply units within the region;
- transform ECF standards for the southeast into timber supply, investment, and growth constraints for representative supply units;
- impose the constraints on the modeling system and compute CPP values for each supply unit;

\(^8\) The geographic area covered by the southeastern regional standards is eastern Mississippi and the coastal plain and central/Piedmont regions of Alabama, Florida, Georgia, North Carolina, South Carolina, and Virginia.
• arrange supply unit land quantities by ascending CPP values to construct an aggregate ECF compensation function.

Our method for performing these tasks is described below.

3.1. Baseline

We develop our baseline using the Southeastern Regional Timber Supply (SERTS) Model. The SERTS model is a version of the Subregional Timber Supply (SRTS) modeling system (Abt et al., 2000) that applies the general timber supply framework described above to specific harvest and inventory data for the southeastern US. SERTS takes current US Forest Service Forest Inventory and Analysis (FIA) data on forest inventories as the initial forest endowment and projects future timber market outcomes specified in Eqs. (1)–(3) based on an evolving set of market and technological conditions over time.

The timber supply function within SERTS takes a Cobb–Douglass mathematical form:

\[ Q_t^s = a P_t^s I_t^s. \]  

Consistent with econometric studies of timber markets (Newman, 1987; Adams and Haynes, 1996), the model maintains relatively inelastic responses to changes in timber prices on the supply side \((\varepsilon = +0.30)\), and inventory elasticity is assumed to be unitary \((\gamma = +1.0)\).

The inventory model within SERTS exactly follows Eq. (3) with a biological function for forest growth derived empirically from the FIA data. Growth is estimated separately by 10-year age classes for two ownership classes (forest industry and other private), two timber types (softwood and hardwood), and five forest types (planted pine, natural pine, mixed pine-hardwood, upland hardwood, and bottomland hardwood).

Subregional detail is a feature of the SERTS modeling system that distinguishes it from other timber market/inventory modeling systems, such as the Forest Service’s TAMM/ATLAS model (TAMM: Adams and Haynes, 1980; ATLAS: Mills and Kincaid, 1992). SERTS defines up to 51 geographically defined FIA survey units across 12 southeastern states, dimensioned across two ownership classes, leading to 102 separate timber supply/inventory units. These units cut across three major physiographic regions (coastal plain, piedmont, and mountains), allowing for a fairly fine degree of resolution for analyzing resource and policy issues. In our application, each of the subregion/owner combinations is a distinct ‘representative owner’ unit.

For the policy simulations, we set the planning horizon to \(T = 30\) years, which is roughly the length of one Southern pine rotation. The SERTS model then generates a 30-year (1995–2024) baseline projection of prices, harvest output levels, and inventories subject to a given set of exogenous market and resource conditions and model parameter values relevant to the southeastern US. The base year of 1995 corresponds to forest conditions represented by the most recent Forest Service FIA data for the seven southeastern states considered in this analysis. The SERTS model solves for the annual regional market equilibrium between the supply system described above and regional demand, expressed here as a (Cobb–Douglass) function of price:

\[ Q_t^D = \beta(t) P_t^o. \]  

Regional timber demand is specified as relatively inelastic \((\eta = -0.50)\) and is assumed to shift over time \([d\beta(t)]\) in magnitudes consistent with the most recent Forest Service Forest and Rangeland Renewable Resources Planning Act (RPA) national timber assessment (Haynes et al., 1995).

Two key resource variables are the total amount of land in the southeastern US timber base over the projection period and the allocation of that land among forest types. Some forest sector-level modeling systems (e.g. those based on intertemporal dynamic optimization algorithms) endogenize land and forest type allocation at the sector level (Adams et al., 1996; Sohngen and Mendelsohn, 1998). However, those models are generally applied to very long-run resource policy issues \((50 + \text{years})\), such as climate change, where the models’ underlying assumptions of freely mobile land and capital are more tenable than they are for the shorter \((0–30\text{-year})\) time horizon evaluated here. For the purposes of this analysis, the
region’s forest land area and forest type allocations are exogenously specified, based on continu-
ations of recent trends and projections from the
national RPA assessment referenced above. Con-
sequently, the size of the southeastern timberland
base is held constant throughout the projection
period, and timberland is expected to change its
allocation among forest types by continuing the
historic trend of conversion of ‘natural’ forests
(e.g. natural pine, mixed hardwood) to planted
pine. Planted pine is projected to grow from just
under 20% of the timberland base in 1995 to
about 30% in 2024 (USDA Forest Service, 1988;
Haynes et al., 1995).

The combination of genetically improved
seedlings, fertilization, and control of competing
vegetation has been shown to significantly en-
hance growth rates of pine plantations on experi-
mental plots in the southeast (Yin et al., 1998). In
reality, observed plantation growth rates have
historically been lower than those on research
plots due to a variety of biological and economic
factors. Therefore, we modify the growth rates
reported by Yin, Pienaar, and Aronov and project
a logarithmic increase of pine plantation yields of
40% over the 30-year projection period on forest
industry plantation land in the baseline. The base-
line growth rate increment was assumed to be less
(20% over 30 years) on nonindustrial pine planta-
tions because of underlying differences in site
quality and capital constraints for that owner
group.

Investment cost estimates are based on a survey
of southern forest management costs from
DuBois et al., (1997) using the following taxon-
omy of forest management costs:
- general forest (GF) management costs
  \[ GF = \text{fire protection} + \text{timber cruising} + \text{timber marking} \]
- pine plantation establishment (PPE) costs
  \[ PPE = \text{site preparation} + \text{planting} \]
- pine plantation post-establishment silvicultural
  (PPS) costs.
  \[ PPS = \text{fertilization} + \text{herbicides} + \text{prescribed burning} + \text{precommercial thinning} \]

Separate data for the coastal plain and pied-
mont regions of the US south were reported for
most categories. Pine plantation costs include all
of the above components. We assume that non-
plantation costs include only the general forestry
component. We estimate average costs per hectare
per year using the reported cost per hectare of
each practice, relative occurrence of practices
across the sampled area, and relative frequency of
application for typical forestry operations in the
coastal plain and piedmont regions. Taken to-
gether, current average management costs are esti-
mated at $25.72 ha\(^{-1}\) year\(^{-1}\) for plantations and
$5.36 ha\(^{-1}\) year\(^{-1}\) for nonplantation manage-
ment in the coastal plain. The corresponding pied-
mont numbers are $26.84 and $7.89, respectively.

3.2. ECF supply constraints

The forest certification standards are structured
in accordance with the FSC’s ten general forest
stewardship principles. Many of these principles
do not directly alter silvicultural practices (e.g.
Community Relations and Workers Rights) and
therefore are difficult to model empirically. As a
result, we focus this analysis on the features that,
in our judgment, are most important and tangible
in terms of their effect on timber supply behavior.
Our objective is to translate the detailed language
of the standards into changes in conditions that
can be analyzed with the market model. The
supply constraints and their relation to the under-
lying FSC forest principles are presented in Table
1.

<table>
<thead>
<tr>
<th>Table 1</th>
<th>Timber supply constraints</th>
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<tbody>
<tr>
<td>1.</td>
<td>Setaside areas</td>
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<tr>
<td></td>
<td>Forest stands over 100 years old in all management types are removed from timber production and reserved in a natural state.</td>
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<tr>
<td>2.</td>
<td>No net conversions to plantations</td>
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<tr>
<td></td>
<td>Conversion of other management types to planted pine is not allowed. Pine plantation area remains at base-year levels.</td>
</tr>
<tr>
<td>3.</td>
<td>Reduced growth on pine plantations</td>
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<tr>
<td></td>
<td>Attainable growth rates on pine plantations are held at current levels due to restrictions on the use of chemical inputs.</td>
</tr>
<tr>
<td>4.</td>
<td>Sustainable yield</td>
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<tr>
<td></td>
<td>Annual harvest can be no greater than annual growth</td>
</tr>
</tbody>
</table>
The first three constraints affect timber supply through their effect on current and future inventories. The standards call for the removal of all primary forest areas from timber production (Constraint 1). Primary natural forests are defined as relatively undisturbed native ecosystems comprising an abundance of mature (old-growth) trees. A threshold age for old growth is not given in the standards. We assigned the 100-year age class designation based on a review of age class and forest type distributions in the FIA data. This constraint leads to the removal of about 4.9% of the region’s hardwood timber inventory volume and 2.7% of the region’s softwood inventory.

The net conversions constraint (2) can be described as altering the baseline management type allocations (conversion of other types to planted pine) to one in which no net conversion occurs. Conversion to planted pine is occurring throughout the region in response to profit opportunities from plantation forestry. Forest plantations grow faster than natural stands and can be cultivated to produce more commercially valuable products. Thus, restricting plantation conversions imposes opportunity costs in terms of the size and composition of the timber inventory.

The constraint on plantation growth rates (3) derives from restrictions on the use of chemicals to fertilize and control pests and competing vegetation. The wording in the certification standards is fairly vague regarding the use of chemicals. Chemicals are clearly discouraged; however, there is implicit recognition that some forms of chemical control may be environmentally preferable to their alternatives (SRFCSP, 1999). For instance, although integrated pest management (IPM) is encouraged, insecticide use may be warranted to prevent catastrophic infestations. Herbicides are an alternative to mechanical site preparation, which can considerably disturb the site. Fertilization is allowed for nutrient-deficient sites. In consultation with scientists on the committee that helped develop the standards, we arrived at the following heuristic to describe the chemical use constraint: chemicals can be used to the extent that they maintain current growth rates. Therefore, the effect of imposing this constraint on our model is that inventories continue to grow at the current growth rates under ECF, instead of the 40 and 20% cumulative increases in growth projected in the baseline. We recognize this is a rather crude implementation of this constraint and therefore include model runs below where no growth rate adjustment is imposed.

From the perspective of softwood (Southern pine) supply, Constraints 1–3 all reduce future softwood inventories relative to the baseline and therefore induce inward supply shifts. On the hardwood side, the setaside constraint (1) as applied removes some hardwood inventory — the area set aside come from all forest types, not just planted pine — which shifts the hardwood supply function. But the conversion constraint (2) mitigates the baseline decline in hardwood inventory by reducing conversions of natural forest types to pine plantations. As an empirical matter, the latter (positive) supply effect for hardwoods, in most cases, will dominate the former (negative) effect, leading to a net outward shift in the hardwood supply function relative to the status quo. Taken together, the welfare gains in the hardwood market can offset some of the losses in the softwood market. We account for these offsetting effects in the analysis.

The fourth constraint imposes the sustainable yield restriction — timber harvest cannot exceed the forest’s growth. Operationally, this is imposed by restating the supply function as the lesser of the ‘optimal’ harvest level or the level of growth:

\[
\tilde{Q}^{s}_t = \min\{Q^{s}_t, G(\cdot)\}
\]

where \(Q^{s}_t = Q^s(P_t)\) is the optimal output determined by the solution of the supply function. In addition to reducing the output level from \(Q^{s}_t\) to \(G(\cdot)\), the sustainable yield constraint reduces the supplier’s welfare by the amount of producer surplus lost (see Appendix A).

3.3. CPP estimates

Strictly speaking, certification constraints apply at the forest level. Because we do not have data on individual forests, we apply these constraints at the supply unit (subregion, owner) level. This simulates the effect of certification on forests that are structured similarly to the structure of a repre-
Table 2
Compensating price premium estimates (%) by ownership: summary statistics

<table>
<thead>
<tr>
<th>Scenario</th>
<th>Low</th>
<th>Medium</th>
<th>High</th>
</tr>
</thead>
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<td>NIPF</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Unweighted mean</td>
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<td>2.8</td>
<td>6.4</td>
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<tr>
<td>Area-weighted mean</td>
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<td>2.1</td>
<td>5.5</td>
</tr>
<tr>
<td>Forest industry</td>
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<td></td>
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<tr>
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<td>8.0</td>
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* All values pooled across softwood and hardwood timber types. Discount rate is 6%.

sentative supply unit. Each supply unit is defined by a unique mix of land area, forest types, inventory volume, species, and age classes. Applying the constraints at this level of resolution allows us to capture differential impacts across these various dimensions of timber supply.

The region subject to the standards is divided into 25 geographic subregions. These subregions cover seven states in the southeastern US and are confined to the coastal plain and piedmont regions of those states. Each subregion can be further divided into two ownership classes, nonindustrial private forest (NIPF) and forest industry, leading to a total of 50 modeled supply units. We evaluated three scenarios, which varied by degree of stringency:10

- low: constraints 1 and 2 only;
- medium: constraints 1, 2, and 3;
- high: all four constraints.

The simulations were run to generate CPP estimates for each of the 50 supply units addressed in the model. The mathematical derivation of the CPP scalar values is presented in Appendix A. Summary statistics by ownership group are presented in Table 2. All CPP values are expressed as a percentage of baseline price ($CT$).

On average, the CPP requirements might be described as relatively modest, but there are substantial differences by scenario and owner group. Taken together, the simulation results indicate that the certification restrictions imposed in the simulations fall most heavily on pine plantation forestry, which is practiced on a much wider scale by industry than by NIPFs. Average CPP requirements are small for both ownership classes in the low scenario (2% range), reflecting the fact that relatively little of the region’s initial inventory is reserved because of the 100-year setaside constraint and that, by itself, the restriction on conversions to plantation is relatively limited. However, when we impose growth rate restrictions on plantations in the medium scenario, this has a substantial effect on CPP requirements for industry suppliers, nearly quadrupling their mean CPP values to 8%. In essence, the growth restriction makes less productive their cumulative investments in plantations over time. The sustained yield constraint added in the high scenario has dramatic effects on both industry and NIPF CPP

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9 The full SERTS model covers up to 12 states and three physiographic regions across the southern US. The five states in the south-central part of the region are covered under separate certification standards as are the mountain areas for the seven states that are included. Results for those areas are not reported here.

10 Another reason Constraints 3 and 4 are added incrementally is because there is a higher degree of uncertainty that these accurately capture the impact of the certification standards. In that regard, treating them incrementally is a rough form of sensitivity analysis.

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Fig. 2. Geographic distribution of compensating price premia (moderate scenario) — forest industry.
3.4. ECF compensation functions

We use the CPP estimates to generate the ECF compensation functions in Fig. 4. Separate functions are presented for each scenario. In all cases, the function starts out with relatively flat sections, representing the low CPP requirements across most of the region’s land base. This primarily reflects the relatively low CPP estimates for NIPFs, who dominate the region’s forest landscape in area owned. However, the compensation function turns upward as we move to the last quarter of land area. This shift upward captures the influx of industry suppliers needing higher compensation levels to offset the restrictions on their otherwise intensive forestry practices. Taken together, the functions in Fig. 4 suggest that a fairly sizable portion of the private land base in the southeast might be amenable to ECF at relatively low price premia based strictly on the opportunity cost of adjusting their current forest management regimes.

4. Conclusions, policy implications, and extensions

Our simulation results suggest that ECF could apparently be practiced with relatively small compensation requirements on a substantial portion of timberland in the southeastern US. In particular, compensation requirements are lower in the piedmont region and for hardwood forests than for softwood forests. These low-compensation forests are concentrated in the hands of NIPF owners, who tend to manage their forests less intensively and have a wider range of species diversity within their forests than their industry counterparts. However, lower compensation to comply with ECF also means less incentive to change current management practices (i.e., small market premia would likely yield only minor changes in behavior). So while the existence of many low-cost adopters may be good for the potential adoption rate of ECF, it might not have
much of an effect on the way land is managed. Higher compensation will be necessary to divert the intensively managed (i.e., higher environmental impact) forests to ECF.

The rewards for less-intensive forestry raise another point about potential consequences of widespread ECF adoption. Less-intensive management of forestland generally requires more extensive use of forestland to produce a given amount of commercial output. Therefore, unless the demand for timber were to decline — in contrast to recent projections (Haynes et al., 1995) — less-intensive forestry could cause forest disturbances to be spread over a wider area (Vincent and Binkley, 1993). This shift can occur both by spreading activity more extensively within the region and/or transferring activity to other US regions or foreign sources. The net environmental quality implications of such changes are ambiguous, a priori.

Before accepting our empirical results as a prediction that certified ECF will in fact be widely adopted with a moderate price premium, we must acknowledge that important hurdles to adoption may exist that are difficult to quantify and thus have remained outside of our analysis. For example, we have not directly accounted for the initial cost and logistical hurdles of developing a management plan and obtaining certification. Preliminary empirical evidence suggests that per-hectare costs of obtaining certification are quite small for large ownerships (e.g. less than a dollar per ha), but may be large for smaller ownerships not enjoying economies of scale (Murray and Casey, 1998). Because much of the southeastern US’s NIPF timberland is held in small units of, for example, less than 40 ha (Moulton and Birch, 1995), the scale economy issue is not inconsequential. Recognizing this, the FSC is considering modifying the certification process to allow small landowners to participate by engaging the services of an FSC-certified forest consultant, rather than developing a full-blown certification of the small forest property. This would allow the small landowner client to avoid the large up-front fixed costs that may serve as an impediment to adoption. To the extent that small landowners can realize this advantage, the initial cost factor may not be too problematic.

Timber suppliers’ willingness to adopt ECF raises several issues related to information problems in the timber market. Many NIPF owners are infrequent participants in timber markets, do not have a formal management plan, and do not employ the services of consulting foresters. The evidence suggests that many NIPF owners forego what seem to be economically rational forest investment opportunities, perhaps because of structural features such as risk aversion (Parks, 1995), credit constraints (Kulivanen, 1990), or informational and technical knowledge shortcomings (USDA Forest Service, 1990). These observed impediments to “optimal” forest management be-
behavior should serve to temper expectations about the scope for seemingly rational adoption of certified forestry practices subject to the relatively moderate price premia estimated here.

Finally, in this paper we have not examined the demand side of certified markets, most particularly the market’s WTP for certified timber. In that regard, the evidence is mixed. Some survey studies have shown potentially large WTP premia (12–20%) for at least some final consumers of wood products (e.g. Winterhalter and Cassens, 1993; Ozanne and Vlosky, 1997). However, these consumers tend to be concentrated in relatively small market niches, and these premia have not yet been widely realized in the timber market (Stevens et al., 1997). The willingness of final consumers to pay a premium may not necessarily transfer directly to timber (stumpage) price premia if there are significant intermediate cost differences between the forest and the consumer. If intermediate costs are higher for certified products, the derived WTP for certified timber falls, all else equal. The intermediate cost factor receiving the most attention in certification studies has been the ‘chain-of-custody’ costs associated with verifying throughout the distribution chain that the wood source is from a certified forest. One study has suggested that chain-of-custody costs are likely modest (Simula, 1996). However, if these costs are not low, they could present a significant impediment to certification, particularly for small, undercapitalized operators. Also of potential importance for operators of all sizes are differences in logging and transportation costs, particularly if the practice of clearcutting is substantially curtailed.

11 As pointed out by one reviewer, chain-of-custody issues may be more problematic for certification in developing country settings, where property rights may not be as well defined as they are in the southeastern US.

12 Toward the end of the standards development process for the southeastern US, restrictions on clearcutting were added, in favor of partial cuts. The corresponding language in the standards was somewhat vague on this point and did not lend itself to empirical analysis in this study. However, studies have shown that logging costs per unit of output rise when logging is restricted to leave part of the stand unharvested (Kluender and Stokes, 1996). Therefore, one might consider this an additional intermediate cost that could negatively affect stumpage values.

In summary, it takes two sides to make a market work. Our analysis suggests a wide range of opportunities may exist for relatively low-cost adoption of ECF practices in the southeastern US. However, adoption of these practices will only be realized if a large body of eco-consumers exists whose WTP for ECF-labeled products is not offset by higher costs for the certified products.

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Appendix A. Computing the CPP scalar with time-variant shifts

This appendix presents the mathematical derivation of annual compensating price premium values \( (t^C) \), first under the simpler case of a nonbinding sustained yield constraint, then under a binding sustained yield constraint. Then, the procedure for reducing time-variant values to a single scalar for the \( T \)-year regime is presented.

A.1. CPP when the sustained yield constraint is nonbinding

From (Eq. (2)) and (Eq. (10)), the specific equation for producer surplus in year \( t \) is

\[
PS_t = xI_t(P_t^t+/t+1)/(\epsilon + 1).
\]
In our empirical analysis, the inventory elasticity is set to $\gamma = 1$, so that term is dropped from the remaining equations. For each, except the final year ($T$), the premium value $\tau^T_i$ equates producer surplus under ECF with baseline producer surplus plus the difference in investment costs:

$$xI^*_t[P_t(1 + \tau^T_i)]^{r+1}/(e + 1)$$

$$= xI^*_t(P_t)^{r+1}/(e + 1) + w_r(X^*_t - X^*_e). \quad (A2)$$

With algebraic manipulation, the solution is

$$\tau^T_i = (\Omega_t/P_t) - 1 \quad (A3a)$$

where

$$\Omega_t = \{(I^*_t/I^*_e)^{r+1}
+ [(e + 1)/xI^*_t][w_r(X^*_t - X^*_e)]\}^{1/(e + 1)}.$$  

$$ (A3b)$$

In the final year, the change in ending inventory term $P_t(I^*_e - I^*_e)$ is added to the right-hand side of (Eq. (A2)) and to the second square-bracketed term on the right-hand side of (Eq. (A3b)).

### A.2. CPP when the sustained yield constraint is binding

Let $Q_{X_t}$ define the constrained harvest level (= growth) in year $t$ (see (Eq. (12)) in the main text). Compute total variable costs as the inverse of the supply function up to the point $Q_{X_t}$:

$$TVC(Q_{X_t}) = \int_0^{Q_{X_t}} P(Q) dQ$$

$$= Q_{X_t}^{(e+1)/e}[\gamma/(e + 1)]*^{[1/(e + 1)]}$$  

$$ (A4)$$

Set the 'target' producer surplus equal to baseline producer, adjusted for investment cost differences:

$$PS_{CX} = P_t(1 + \tau^T_i)*Q_{X_t} - TVC(Q_{X_t})$$

$$= PS^* + w_r(X^*_t - X^*_e) \quad (A5)$$

We can then solve for the year $t$ CPP value as follows:

$$\tau^T_i = \{PS^* + w_r(X^*_t - X^*_e) + TVC(Q_{X_t})\}/(P_tQ_{X_t})$$

$$= -1.$$  \quad (A6)

### A.3. Estimating scalar CPP value for the regime

In general, the value of $\tau^T_i$ will vary across time periods. To reduce this value to a scalar value capturing CPP effects for the entire regime, we weight each period’s $\tau^T_i$ value by a share equal to that period’s contribution to the total baseline forest asset value, as defined in (Eq. (8)). For years 0 to $T - 1$, the weights are computed as follows:

$$W_t = [PS^* - w_rX^*_t]e^{-rt}/V^*.$$

$$ (A7)$$

In year $T$, the ending inventory term is added to the bracketed term in (Eq. (A7)).

The scalar, $\tau^CT$, is then the present value share-weighted sum of the $\tau^T_i$ values:

$$\tau^CT = \sum_{t=1}^{T} W_t\tau^T_i.$$  \quad (A8)

### References


Winterhalter, D.M., Cassens, D., 1993. Consumer perceptions of forest sustainability and willingness to pay: Results of a national survey. Purdue University, West Lafayette, IN.