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OPTIMAL FOREST CONSERVATION: COMPETITIVENESS VERSUS GREEN IMAGE EFFECTS***

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ABSTRACT: This paper provides a theoretical framework to study the behavioral and welfare effects of forest conservation, which leads to a binding harvesting constraint for landowners. The economy is modeled as a three-stage game by the interaction of the government's conservation policy, with consequent adjustments in domestic timber market, and in output determination in a Cournot rivalry with the foreign forest industry. More specifically, we study how forest industry's competitiveness constrains forest conservation and whether the "green image" demand resulting from forest conservation compensates the loss in competitiveness. It is shown that although the green image effect may locally be strong enough to even increase the profits of domestic forest industry, at the socially optimal forest conservation level it never dominates the competitiveness effect. Hence, there is a trade-off between forest conservation and the competitiveness. These findings are robust to the issue of whether timber markets are perfectly or imperfectly competitive.

Additional Keywords: biodiversity, harvesting constraint, timber price bargaining

JEL classification: Q23, L73, J51

1. INTRODUCTION

Intensification of timber production and silviculture together with tropical deforestation has incurred considerable losses of original species, habitats and ecosystems, threatening severely biodiversity of world forests.[1] The problems and tasks in designing biodiversity conservation programs differ considerably across countries. While stopping the deforestation is the most central issue in tropical forests, the main focus in Northern boreal forests is at preserving habitats and local ecosystems for rare and endangered species. This requires that some old forests is preserved entirely and silvicultural and harvesting methods are chosen so as to promote diversity in forests.

The issue of how to model biodiversity in a detailed way for forest management purposes is both a challenging and widely unexplored area. While Weitzman (1998) has suggested a cost-effectiveness methodology to rank projects for biodiversity conservation with the special focus is on species, approaches in forestry follow a different route due the special focus on habitats and local forest ecosystem. Forestry applications include e.g. diversity indeces for tree size or tree species diversity,[2] biodiversity included as one of the several land-management objectives (Montgomery et al.1999) and spatial optimization analyses that account for wildlife edge effects through multiple habitat needs in a multistand forest management problem (Bevers and Hof 1999).

Conserving habitats and local forest ecosystems requires timber allocated out of forestry. Morever, many means of promoting biodiversity conservation within commercial forests tend partially to reinforce this conservation effect. Based on these considerations we ask: *what are the effects of forest conservation not only on the forest sector but also on the rest of the economy, and how do these effects in turn restrict the possibilities for forest conservation*? The initial consequence of forest conservation must show up either in higher management costs or reduced harvesting possibilities. These effects shift first to

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[1] The term biodiversity refers to the variety and multiformity of life. Even though it is impossible to give a precise definition to biodiversity, the term refers especially to the diversity of species, to the genetic variety of species and populations, and to the diversity of habitants and ecosystems (see e.g. Hunter 1990 for a more detailed description).

[2] The literature here is voluminous, see e.g. Buongiorno, Dahir, Lu and Lin (1994) and Buongiorno, Peyron, Houllier and Bruciamacchie (1995), Niese and Strang (1992), Önal (1997), and for a more general treatment of diversity, Baczkowski, Joanes and Shamia (1997).

timber prices with the consequent repercussions to other sectors of economy and thereby to social welfare. While some argue that conservation threatens the competitiveness of domestic forest industries, some point out that this is only a part of the truth. If forest conservation leads consumers to perceive wood products as being of higher quality, the resulting "green image" increases timber demand and will have a positive effect on market share, profits and welfare, ceteris paribus.

More specifically, to study how international competitiveness of domestic forest industry constraints possibilities for forest conservation, and what happens if this conservation requirement induces consumers to perceive woods products as being of higher quality. We consider the economy, where forest industries at home and abroad produce and export forest products. Forest conservation shows up to landowners as a binding harvesting constraint. The firms in both countries face a downward-sloping demand for forest products. The benchmark case assumes homogenous product, under which harvesting constraint has only the cost effect for the domestic industry, but does not directly affect the demand for wood products. This is compared with the case, where also the green image effect of products due to forest conservation policy matters.

In order to check the robustness of results, we analyze conservation under two alternative hypotheses: the perfectly competitive timber market, and the imperfectly competitive market, where timber price is assumed to be negotiated between the representatives of the forest owners' association and the forest industry.[3] While the former is applicable to the United States of America, the latter may be more relevant for Scandinavian countries.

The interaction between the government, the forest industry and the landowners in the domestic economy is modeled as a three-stage game. *In the first stage,* government credibly commits to its forest conservation policy, which shows up as a harvesting constraint. *In the second stage* timber price is determined either in competitive market or the forest industry and the forest owners' association bargain over the timber price. Finally, *in the third stage* the domestic forest industry taking the timber price as given chooses

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3 Koskela and Ollikainen (1998) and Bergman and Brännlund (1995) provide in various ways empirical evidence on timber market imperfections in Finland and Sweden, respectively.

both its input levels and its wood products as a part of its Cournot rivalry with the foreign forest industry.

The paper proceeds as follows. In section 2 we first look at the last stage of the game, the Cournot competition between home and foreign country industries in the woods product market, and then the second stage of the game, namely the determination of timber price. Section 3 studies the first stage of the game by providing a welfare analysis of forest conservation when government behaves as a Stackelberg leader towards the private sector. Finally, some concluding remarks are presented in section 4.

2. FOREST CONSERVATION, GREEN IMAGE EFFECT AND COMPETITIVENESS OF FOREST INDUSTRY

We solve our model backwards by starting from the last stage of the game, i.e., with the competition between domestic and foreign industry.[4] The domestic forest industry uses capital k and timber *x* as the factors of production to produce woods product y according to a Cobb-Douglas production technology with constant returns to scale $y = f(k,x) = k^{1-a}x^{a}$, where $0 < a < 1$ describes the elasticity of output with respect to timber. Denoting the price of capital and timber by r and p, respectively, the cost function of the firm can be expressed as

[1] $$C(p,r,y) = A\left[r^{1-a}p^{a}\right]y = c(p,r)y \, .$$

where c(p,r) denotes the average and marginal cost of production with $c_p, c_r > 0$ and $A = a^{-a}(1-a)^{a-1}$.

We model the green image effect as follows. Consumers of wood products are assumed to regard products from "regular forests" as the standard quality (denoted by u_2) products, while wood products from forests, where biodiversity is actively conserved are regarded as

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4 For a general methodological treatment of the issues involved, see e.g. Fudenberg and Tirole (1991, Chapters 3-4).

higher quality products denoted by $u_1 = u_1(\overline{m})$ with $u_1'(\overline{m}) > 0$.[5] By scaling $u_2 = 1$ (which implies that $u_1 > 1$) one can define *the relative quality factor* θ as $\theta = u_1/u_2 = u_1$ with $\theta'(\overline{m}) > 0$. Following the standard approach in the theory of vertical product differentiation we assume a linear indirect utility function $U = \alpha\theta - q$, where q is the product price. This utility function gives rise to the following linear inverse aggregate demands for the high quality home and the standard quality foreign wood products (see e.g. Motta 1993 for details)

[2a] $q = \theta(\alpha - y) - y^*$

[2b] $q^* = \alpha - y^* - y$,

where *y** is the output of the foreign industry, and *q*, *q** are the product prices of domestic and foreign outputs, respectively. Specification [2a] indicates that when the product quality increases, the firm can charge a higher price for any given quantity. For the homogenous products we have $\theta = 1$, so that the aggregate demand is thus given by $q = \alpha - y - y^*$.

2.1 Third Stage of the Game: Cournot Competition in the Wood Products Market

The domestic and foreign industry's profit functions can be written respectively as $\tilde{\pi}(y, y^*) = (q - c(p,r))y$ and $\tilde{\pi}^*(y, y^*) = (q^* - c^*(p^*, r^*))y^*$. The first-order conditions for the Cournot equilibrium in the exogenous vertical product differentiation (the green image case) are

[3a] $\tilde{\pi}_y = [\theta(\overline{m})(\alpha - 2y) - y^*] - c = 0$

5 Product/forestry management certificates are typically regarded as an example of the importance of the "green image" or "green label" of products. See e.g. Mattoo and Singh (1994), and Swallow and Sedjo (2000) for a graphical analysis of voluntary and mandatory eco-labelling, respectively. As for the goals on potential forms of forest certification, see e.g. Bass (1997), for forest certification in USA see e.g. Stevens, Ahmad and Ruddell (1998) and for potential markets for certified forest products in Europe see Rametsteiner, Schwartzbauer, Juslin, Kärnä, Cooper, Samuel, Becker and Kuhn (1998). Ozanne and Smith (1998) as well as Barbier, Burgess, Bishop and Aylward (1994) report some survey evidence on the magnitude of the green image effects.

[3b] $\tilde{\pi}^*_{y^*} = [\alpha - 2y^* - y] - c^* = 0$.[6]

Equations [3a] - [3b] describe the usual *MR = MC* rules for the output determination. The second-order and stability conditions are

[4a] $\tilde{\pi}_{yy} = -2\theta(\overline{m}) < 0$, $\tilde{\pi}^*_{y^*y^*} = -2 < 0$

[4b] $\Delta = \tilde{\pi}_{yy}\tilde{\pi}^*_{y^*y^*} - \tilde{\pi}_{yy^*}\tilde{\pi}^*_{y^*y} = 4\theta(\overline{m}) - 1 > 0$

where $\tilde{\pi}_{yy^*} = \tilde{\pi}^*_{y^*y} = -1 < 0$. Conditions [4a] -[4b] ensure that output reaction functions slope downwards and that the equilibrium is stable and unique. Table 1 of Appendix reports comparative statics. A rise in domestic timber price decreases domestic and increases foreign output, while the opposite holds for foreign *p**. Higher domestic product quality with constant factor prices increases domestic output and timber demand and decreases foreign output.[7] Hence, we have

[5a] $y = y(\underset{-}{p}, \underset{+}{p^*}, \underset{0/+}{\theta(\overline{m})})$

[5b] $y^* = y^*(\underset{+}{p}, \underset{-}{p^*}, \underset{0/-}{\theta(\overline{m})})$

The dependence of domestic timber demand on exogenous parameters can be given as $x^d = x^d(\underset{-}{p}, \underset{+}{p^*}, \underset{0/+}{\theta}(\overline{m}))$.

Figure 1 represents the stable Cournot equilibrium in the output space (y, y^*) at the point a and curves *AA* and *BB* describe the reaction curves for the domestic and foreign forest industry as a function of the foreign (domestic) output in the case of homogenous products, respectively. Allowing for the quality diffference of the wood products shifts the

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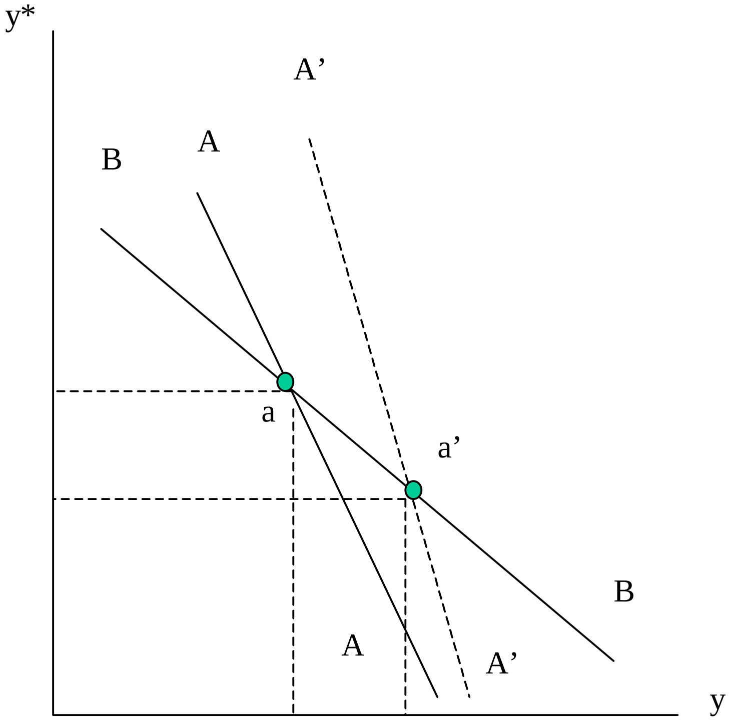
6 In this paper the derivatives are noted by primes for functions with one argument and by subscripts for partial derivatives of functions with many arguments. Hence, for example, $\theta'(\overline{m}) = \partial\theta(\overline{m})/\partial\overline{m}$ while $A_x(x, y) = \partial A(x, y)/\partial x$ etc.

7 Notice, however, that in general equilibrium also domestic timber price increases, as the valuation of the quality of wood products increases.

reaction curve of the domestic industry output outwards making it also steeper in the output space (y, y^*) as indicated by A'A' .[8]

Figure 1. *Stable Cournot Equilibrium*



2.2 Second Stage of the Game: Timber Price Determination

Next we ask: what happens to timber price, when forest conservation increases and the harvesting constraint becomes tighter? In order to get background for timber price analysis, we first analyze the relationship between the harvesting constraint and the landowner's reservation price.

A. Forest conservation and the reservation price

Consider a representative landowner who's preferences can be described by a static quasi-linear utility function

[6] $U = px + v(m)$.

8 To confirm this notice that $A'A' = -\tilde{\pi}_{yy^*}/\tilde{\pi}_{yy} = -1/2\theta(\overline{m})$, while $AA = -\tilde{\pi}_{yy^*}/\tilde{\pi}_{yy} = -1/2$.

In equation [6] x is harvesting and p timber price. Forest stock, $m = Q - x$, where Q is the initial timber stock, provides amenity services with a concave valuation function $v(m)$, $v'(m) > 0$ and $v''(m) < 0$. This is in line with the large body of forest economics literature which, starting from Hartman (1976), argues that landowners are interested in harvest revenue and recreational services.

The requirements of forest conservation can be expressed in its simplest form as a permanent loggin ban to landowners. If it is binding the representative landowner would like to harvest more than allowed, but $\overline{m} \le m$ must hold. Maximizing now [6] with respect to x subject to $\overline{m} \le m$ yields

[7] $$p - [v'(m) + \lambda] = 0,$$

where λ is the shadow price of the harvesting constraint.

The harvesting constraint makes timber supply price inelastic, i.e. $x_p = 0$ implying that $x^s = x^s(\overline{m})$, with $x^s_{\overline{m}} = -1$, i.e., timber stock increases and harvesting decreases one-to-one as a result of introducing the harvesting constraint.[9] The harvesting constraint also affects the reservation price of timber, i.e. the price under which the landowner is indifferent between harvesting and not harvesting. This is obtained by asking what timber price would make the landowner indifferent between harvesting to the constrained level, the associated utility being $U = px + v(\overline{m})$, versus not harvesting at all with the utility $U^0 = v(Q)$. By setting $U = U^0$ one gets the reservation price, $p = e$.

[8] $$e \equiv \frac{v(Q) - v(\overline{m})}{Q - \overline{m}}.$$

Landowner does not sell when $e > p$, but decides to sell when $e \le p$. It is easy to see that $e = e(\underset{+}{\overline{m}}, \ldots)$. Tighter binding harvesting constraint decreases the welfare of landowner by

9 In order to simplify the analysis we assume (somewhat unrealistically) that all landowners are rationed. If we had assumed that some landowners face binding harvesting constraint, while the rest do not, then the aggregate timber supply would not be totally price inelastic like. This complication would not, however, change qualitative results.

the amount λ and to compensate this welfare loss the landowner raises the reservation price at which he is willing to sell. Armed with these findings, we move on to analyze the timber price determination in competitive and incompetitive timber markets.

B. The Effect of Forest Conservation on Timber Price

In the economics literature there is no unique and standardized way of characterizing the intensity of competition. In traditional oligopoly models the consequences of decreased competition are analyzed by decreasing the number of competitors. Another approach, frequently applied in the area of industrial organization, is to measure the intensity of competition by the degree of product differentiation like, for example, in the Hotelling type models of horizontal differentiation. A third way of capturing the degree of competition is to identify it with the relative bargaining powers of both sides of the market, i.e. to apply the Nash bargaining approach. This is the approach we adopt in what follows. Hence the timber price is assumed to be determined as the outcome to a Nash bargaining process between the representatives of the domestic industry and the landowners subject to the constraint that the domestic industry unilaterally decides upon timber use.

We assume that the zero profit represents the threat point (π^o) of the domestic industry so that the forest industry tries to maximize $\tilde{\pi} - \pi^o = \pi$. The forest owners's association has the target function $\tilde{V} = px + v(\overline{m})$, while $V^o = v(Q)$ represents its the threat point. Under timber price bargaining the forest owners' association tries to maximize $V = \tilde{V} - V^o = px - (v(Q) - v(\overline{m}))$. Utilizing equation [8] we can rewrite V as follows

[9] $$V = (p - e(\overline{m},...))x.$$

Determination of the timber price can be modeled as the solution to the following Nash bargaining problem[10]

[10] $$Max_p\ \Omega = V^{\beta}\pi^{1-\beta} \qquad \text{s.t. } x^d = x^d(p, p^*, \theta(\overline{m}))$$

10 This can be justified either axiomatically (see Nash 1950) or by using the non-cooperative sequential bargaining approach (see Binmore, Rubinstein and Wolinsky 1986).

with β and $1-\beta$ representing the relative bargaining power of the forest owners' association and the domestic industry, respectively, and where we have made the natural assumption that the forest industry unilaterally decides upon timber used. The first-order condition for this problem can be expressed as

[11] $$\Omega_p = 0 \Leftrightarrow \beta\frac{V_p}{V} + (1-\beta)\frac{\pi_p}{\pi} = 0 .$$

Since $\pi_p = -y[c_p + y_p^*] < 0$ we have $V_p = (x/p)[p(1-\eta) + e\eta] > 0$, where $\eta = -(x_p^d p)/x$ is the own-price elasticity of timber demand, which is not constant despite the use of the Cobb-Douglas production function, because the demand function for wood products is linear. Due to $\pi_p < 0$ a rise in the relative bargaining power of the forest owners' association leads to a higher timber price.

Equation [11] can be re-expressed as a function of the relative bargaining power β and other exogenous parameters as follows

[12] $$\Omega_p = 0 \Leftrightarrow \quad p\left[\beta(2\alpha(2\theta-1) - 2c + c^*)(1-\eta) - (1-\beta)4sc\right] + e\left[\beta(2\alpha(2\theta-1) - 2c + c^*)\eta + (1-\beta)4sc\right] = 0,$$

where $s = px/cy$ is the cost share of timber in production. The homogenous case is readily obtained from equation [12] by setting $\theta = 1$ so that we have

[13] $$\Omega_p^{ho} = 0 \Leftrightarrow \quad p\left[\beta(2\alpha - 2c + c^*)(1-\eta) - (1-\beta)4sc\right] + e\left[\beta(2\alpha - 2c + c^*)\eta + (1-\beta)4sc\right] = 0$$

Assuming that the second-order condition, $\Omega_{pp} = \frac{\beta}{V^2}(VV_{pp} - V_p^2) + \frac{1-\beta}{\pi^2}(\pi\pi_{pp} - \pi_p^2) < 0$, for Nash bargaining holds, equations [12] and [13] define the negotiated timber price as a function of exogenous parameters. The implicit differentiation of [11] gives $p_{\overline{m}} = -(\Omega_{p\overline{m}})/\Omega_{pp}$ so that sign $p_{\overline{m}}$ = sign $\Omega_{p\overline{m}}$. From the first-order condition [12] one obtains

[14] $$\Omega_{p\overline{m}} = \beta 4\alpha\theta'(\overline{m})\left[p(1-\eta)+e\eta\right] + e_{\overline{m}}\left[\beta(2\alpha(2\theta(\overline{m})-1)-2c+c^{*})\eta+(1-\beta)4sc\right]$$
$$-\eta_{\overline{m}}(p-e)\left[\beta(2\alpha(2\theta(\overline{m})-1)-2c+c^{*})\right] > 0\,,$$

where $e_{\overline{m}}$, $\theta'(\overline{m}) > 0$, and $\eta_{\overline{m}} < 0$ (see Appendix for the derivative $\eta_{\overline{m}}$).

Taking the case of homogenous products, one gets from equation [14] by setting $\theta'(\overline{m}) = y_{\theta} = 0$ that

[15] $$\Omega^{ho}_{p\overline{m}} = \left[\beta(2\alpha + c^{*} - 2c)\eta + (1-\beta)4sc\right]e_{\overline{m}} > 0$$

Hence, we can summarize

Result 1. *Under Nash bargaining a binding increase in forest conservation increases the bargained timber price with and without the green image effect.*

Result 1 has a natural interpretation. In the homogenous goods case only the reservation price effect is operative, i.e., landowners will require higher timber price to compensate for the rationing of harvesting. In the presence of the induced green image effect two additional reinforcing channels of influence exist. First, higher demand makes the forest industry more willing to pay higher timber price, and moreover, as the price elasticity of the demand for timber decreases, it becomes less costly for the forest owners' association to demand higher timber price.

In the case of competitive timber markets, timber price is determined as a solution to $x^{d}(p, p^{*}, \theta(\overline{m})) = x^{s}(\overline{m})$. It is straightforward to see that $p^{c}_{\overline{m}} > 0$. In the homogenous product case tighter harvesting constraint decreases timber supply, which leads to a higher timber price. If forest conservation induces higher demand for wood products and thereby higher timber demand, the timber price increase is even larger. Thus we can summarize

Result 2. *Under competitive timber markets a binding increase in forest conservation increases the equilibrium timber price without and with the green image effect.*

2.3. Forest Conservation, Competitiveness and Profits

What are the effects of conservation on competitiveness, profits and market share of the domestic industry? When conservation requirement becomes tighter, competitiveness, defined as an inverse change in relative unit costs of production,[11] deteriorates. To obtain the effects on the profits of industries at home and abroad, when $\overline{m}$ is changed, we use the envelope theorem and differentiate the indirect profit functions (which we denote with hats) $\hat{\pi}$ and $\hat{\pi}^*$ with respect to $\overline{m}$ so as to get [12]

[16a] $$\frac{d\hat{\pi}}{d\overline{m}} = -yp_{\overline{m}}[c_p + y_p^*] + yq_\theta \theta'(\overline{m}) = ?$$

[16b] $$\frac{d\hat{\pi}^*}{d\overline{m}} = -y^* y_p p_{\overline{m}} < 0$$

where $q_\theta = (\alpha - y) > 0$ and $p_{\overline{m}} > 0$ regardless of the degree of competition in timber markets. Under homogenous product case $d\hat{\pi}/d\overline{m} = -yp_{\overline{m}}[c_p + y_p^*] < 0$ and $d\hat{\pi}^*/d\overline{m} = -y^* y_p y_{\overline{m}} > 0$. To obtain the effects on market shares, we differentiate totally the system [7a] - [7b] with respect to $\overline{m}$ and solving for $dy/d\overline{m}$ and $dy^*/d\overline{m}$ so as to yield

[17a] $$\frac{dy}{d\overline{m}} = \underbrace{y_\theta \theta'(\overline{m})}_{+} + \underbrace{y_p p_{\overline{m}}}_{-} \begin{cases} < 0 & for\ \theta'(\overline{m}) = 0 \\ = ? & for\ \theta'(\overline{m}) > 0 \end{cases}$$

[17b] $$\frac{dy^*}{d\overline{m}} = \underbrace{y_\theta^* \theta'(\overline{m})}_{-} + \underbrace{y_p^* p_{\overline{m}}}_{+} \begin{cases} > 0 & for\ \theta'(\overline{m}) = 0 \\ = ? & for\ \theta'(\overline{m}) > 0 \end{cases}$$

In the presence of induced green image effect, higher forest conservation rate affects domestic forest industry through two channels. Demand for wood products increases and this is counter-affected by higher productions costs so that the overall effect remains a priori ambiguous. For the homogenous goods only the cost effect is relevant so that the market share of domestic (foreign) industry decreases (increases).

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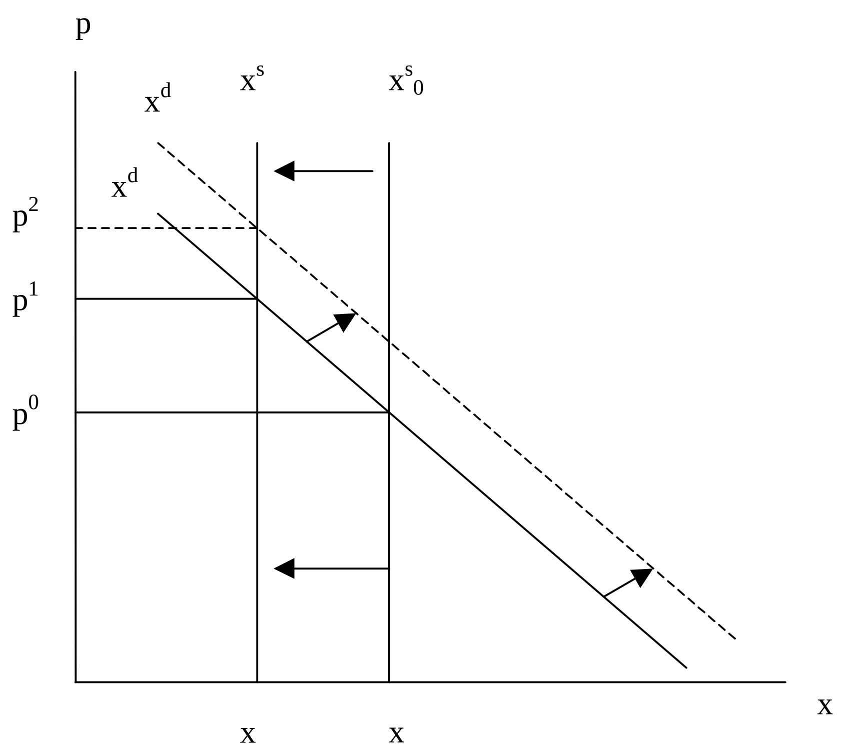
[11] This is in line with Alesina and Perotti (1997) where the term "competitiveness" is defined as "unit … costs in manufacturing in one country relative to its competitors" (p. 921).

Recalling that a rise in forest conservation decreases the use of timber as a factor of production, one can ask whether it is possible for domestic production to increase. The answer is positive. Figure 2 shows what happens in competitive timber market. Initial timber demand x_0^d is downward-sloping and timber supply is a vertical line x_0^s. Higher conservation rate shifts timber supply left to x_1^s and the equilibrium timber price increases from p^0 to p^1 for a given demand. Due to the green image effect timber demand curve moves outwards to x_1^d so that the equilibrium timber price increases further from p^1 to p^2. Both green image effect and timber price-induced cost effect increase the demand for capital. Provided that the increase in capital used is strong enough domestic production may even increase.[13]

Figure 2. *The effects of an increase in conservation on timber market*



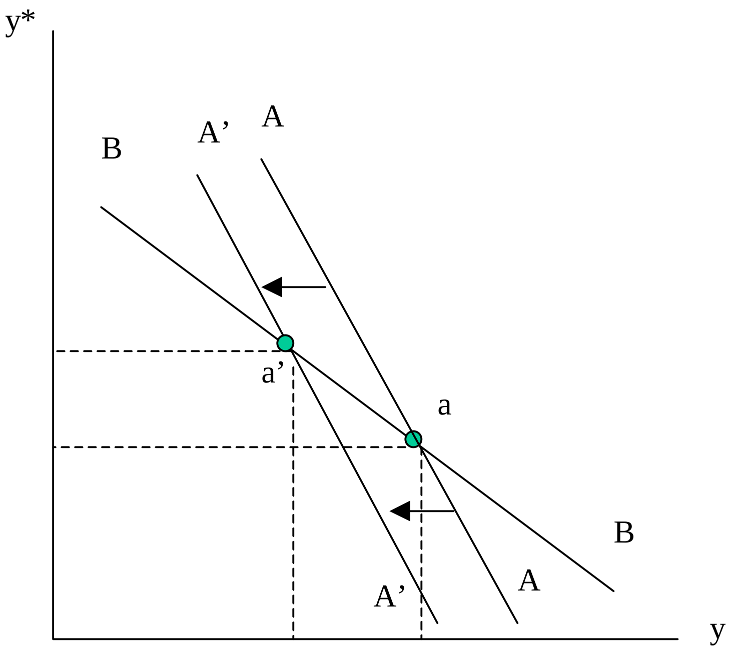
We can summarize the findings in

12 For the envelope theorem, see e.g. Mas-Colell, Whinston and Green (1995, 964-966).

Result 3. *Regardless of the degree of competition in timber markets a binding increase in forest conservation (a) weakens international competitiveness, decreases the profits and market share of domestic industry under homogenous product case, while (b) the induced green image effect counteraffects the profits and market share effecs and may even locally dominate them.*

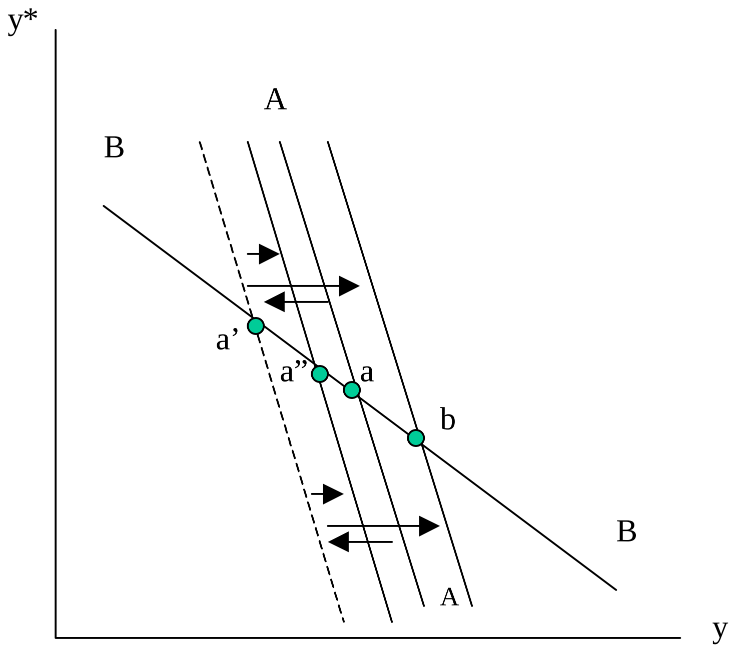
Figure 3a shows the the case of homogenous products. The original equilibrium is at the point *a*. A higher forest conservation requirement shifts the reaction curve of domestic industry AA inwards yielding a new equilibrium at point *a'* with a smaller domestic, but higher foreign production. Figure 3b illustrates the green image case with a steeper slope of domestic reaction curve. A higher $\overline{m}$ shifts domestic reaction AA curve inwards to point *a'* due to the competitiveness effect. As a rise in forest conservation induces consumers to perceive domestic product of being higher quality, the demand for domestic woods products goes up and the domestic reaction curve shifts outwards. Depending on the relative strengths of the demand and cost effects, domestic forest industry may end up somewhere between *a* and *a'* (say *a''*), in which case the decrease in production is less than under homogenous products case, or even beyond *a* (point *b*) indicating higher output than in the original equilibrium.

Figure 3a. *Tighter domestic conservation requirement: homogenous products*



[13] The comparative statics of capital demand is available from the authors upon request.

Figure 3b. *Tighter domestic conservation requirement: green image effect*



3. FIRST STAGE OF THE GAME: A WELFARE ANALYSIS OF FOREST CONSERVATION

We now turn to look at welfare issues of forest conservation. The modern analysis of strategic environmental policy under imperfectly competititive goods market focuses on the question on how the government should choose taxes and subsidies to get rents to domestic industry (for a recent survey about this literature see Ulph 1997). Here we follow a different route, and assume in the line of conventional welfare analysis that the government credibly chooses $\overline{m}$ by maximizing social welfare function, and has no other instruments available. In game-theoretic terms this means that government is the Stackelberg leader with respect to the private sector**.** Since we are interested in the international competitiveness and social welfare aspects of conservation we *assume that the government maximizes the social welfare function and not the rents to domestic industry*.[14]

[14] This also lies in conformity with the Agenda 2000 for biodiversity conservation accepted in the United Nations' Rio Conference 1992.

When a part of wood products is consumed by domestic consumers and the rest is exported the consumers' surplus in the green image case is given by $CS^{he} = \frac{1}{\theta}\int_{q}^{\alpha\theta - y^*}\left[\alpha\theta - y^* - q\right]dq = \frac{1}{2\theta}\left[\alpha\theta - y^* - q\right]^2 = \frac{y^2}{2}$, where $y = \frac{1}{\theta}(\alpha\theta - y^* - q)$ The homogenous goods case is obtained by setting $\theta = 1$.[15]

The government chooses $\overline{m}$ so as to maximize the sum of domestic producers' surplus from forest production, domestic consumers' surplus from consumption and public goods valuation of the standing stock,

[18] $$\max_{\{\overline{m}\}} W = PS + CS + (n-1)v(\overline{m}),$$

where producers' surplus (PS) is the sum of total rents by the forest owners' association and forest industry, i.e. $PS = \hat{V} + \hat{\pi}$. The term $(n-1)v(\overline{m})$ refers to the valuation of non-forest owners' utility from conservation indicating that biodiversity conservation is regarded as a public good. The number of nonlandowners is given by $(n-1)$ and without a loss of generality we assume that their biodiversity valuation function is identical to that of the representative landowner.

We consider first the case where timber price is determined as a result of Nash bargaining. The first-order condition for the welfare maximization is

[19] $$\frac{dW}{d\overline{m}} = \underbrace{\frac{d\hat{\pi}}{d\overline{m}}}_{-} + \underbrace{\frac{d\hat{V}}{d\overline{m}}}_{+/-} + \underbrace{CS_{\overline{m}}}_{-} + \underbrace{(n-1)v'(\overline{m})}_{+} = 0,$$

where

[20] $$\frac{d\hat{V}}{d\overline{m}} = \underbrace{V_{\overline{m}}}_{-} + +\underbrace{V_p p_{\overline{m}}}_{+} + \underbrace{V_\theta \theta'(\overline{m})}_{+} \begin{cases} = ? & if \;\; \theta'(\overline{m}) = 0 \\ = ? & if \;\; \theta'(\overline{m}) > 0 \end{cases}$$

[21] $$\frac{d\hat{\pi}}{d\overline{m}} = \underbrace{\hat{\pi}_{\overline{m}}}_{+} + \underbrace{\hat{\pi}_p p_{\overline{m}}}_{-} \begin{cases} < 0 & if \;\; \theta'(\overline{m}) = 0 \\ = ? & if \;\; \theta'(\overline{m}) > 0 \end{cases}.$$

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15 See Eaton and Grossman (1986) for a similar treatment of consumers' surplus in a different context.

[22] $$CS_{\overline{m}} = yy_{\overline{m}} \begin{cases} < 0 & if\ \theta'(\overline{m}) = 0 \\ = ? & if\ \theta'(\overline{m}) > 0 \end{cases}.$$

For the homogenous products, we have $\theta'(\overline{m}) = 0$, so that $d\hat{\pi}/d\overline{m} < 0$ and $CS^{ho}_{\overline{m}} = yy_{\overline{m}} < 0$, while the total effect on the forest owners' association remains, however, ambiguous because $\hat{V}_{\overline{m}} = -e_{\overline{m}}x < 0$ and $\hat{V}_p p_{\overline{m}} > 0$. Hence, constraint on the harvestable timber stock brings a burden to the forestry industry and domestic consumers, a gain to non-forest owners, but the effect on the forest owners' association remains ambiguous.

To summarize, we have

Result 4. *In the homogenous products case and timber price bargaining, welfare maximizing forest conservation is carried out to the point, where the marginal benefit to non-forest owners is equal to the sum of welfare loss for forest industry, the forest owners' association and consumers.*

Economic interpretation of Result 4 is natural. Higher conservation level increases the welfare of recreationalists and raises timber price, which decreases industry profits and via increased product price consumers' surplus. The effect of conservation on forest owners' association is ambiguous, because, on the one hand it hurts landowners via reduced harvesting possibilities and on the other hand benefits them via increased timber price. while its In the precence of green image effects the size of the induced demand effect $\theta'(\overline{m})$ matters as well. But since $(n-1)v'(\overline{m}) > 0$, we must have that $PS^{he}_{\overline{m}} + CS^{he}_{\overline{m}} < 0$ at the interior optimum, though less than in the absence of the green image effect. Hence we have

Corollary 1. *If forest conservation raises demand for the woods product via the green image effect, the optimal conservation rate increases, but at the interior optimum the green image effect never dominates the competitiveness effect.*

The dominance of the competitiveness effect over green image effect at the social optimum is natural, since it is never optimal the preserve all the forests for biodiversity conservation. Hence, though socially optimal conservation is higher under green image effect, the forest sector rent effect, i.e., the sum of the welfare loss of landowners and forest industry, remains negative. Corollary 1 indicates that forest conservation has its costs; the country is willing to give up some monetary income in order to obtain nonpecuniary benefits from conservation though naturally in the presence of green image effect this trade-off is smaller.

For the competitive timber market the details of the welfare analysis of landowners are slightly different from the bargained case. The indirect utility function of the representative landowner under the permanent harvesting constraint can be written as $\hat{U} = \hat{U}(\overline{m}, p...)$. Using the envelope theorem one gets $\hat{U}_{\overline{m}} = -p + v' = -\lambda < 0$ and $\hat{U}_p = x > 0$. Therefore the welfare effect on the representative landowner can be expressed as

[23] $$\hat{U}_{\overline{m}} + \hat{U}_p p^c_{\overline{m}} = \left[-\lambda + xp^c_{\overline{m}}\right] = ?\,,$$

where $p^c_{\overline{m}} > 0$. Equation [23] corresponds the term $d\hat{V}/d\overline{m}$ in [18]. Hence, as in the case of Nash bargaining the welfare effect of the harvesting constraint on the landowner is ambiguous. Tighter harvesting constraint hurts the landowner ($\hat{U}_{\overline{m}} = -\lambda < 0$), but reduced supply increases timber price so that the landowner becomes better-off for this reason ($\hat{U}_{\overline{m}} p^c_{\overline{m}} > 0$). The term $d\hat{\pi} / d\overline{m}$ remains ambiguous, and the effect on consumers' surplus is qualitatively similar as previously. Hence, we can conclude

Corollary 2. *The welfare analysis of forest conservation does not qualitatively depend on whether timber market is perfectly or imperfectly competitive.*

4. CONCLUDING REMARKS

This paper has provided a theoretical framework to study the relationship between forest conservation, international competitiveness of the domestic forest industry and social welfare with and without the green image effect in the demand for wood products. The behavior of the domestic economy was modeled as a three-stage game. In the first stage the government as the Stackelberg leader announces its forest conservation policy and credibly commits to it. In the second stage the forest industry and the forest owners' association bargain about timber price or alternatively timber price is determined in competitive timber markets. In the third stage the domestic industry determines output in a Cournot rivalry with foreign forest industry.

The paper has shown that when forest conservation becomes binding, the timber availability falls and the reservation price of timber for forest owners' association increases. Regardless of the competitive nature of timber markets timber price goes up.This weakens the international competitiveness of the domestic forest industry and thereby decreases its market share, ceteris paribus. If tighter forest conservation leads consumers to perceive products as being of higher quality – the induced green image effect - then the demand for domestic woods products increases, which counteraffects the competitiveness effect.

A welfare analysis was carried out by assuming that government maximizes the sum of producers' and consumers’ surpluses and accounts for the valuation of biodiversity as a public good. In the benchmark case of homogenous product welfare maximizing forest conservation should be set so as to equalize the marginal benefits to nonlandowners and to the marginal cost, i.e., the sum of welfare loss for consumers, forest industry and the forest owners' association. If conservation leads consumers to perceive product as being of higher quality, the optimal conservation of forest stock is higher than in the homogenous goods case.

Our analysis has been conducted on the assumption that the timber price in the foreign country is exogenous. Examining a parallel timber price determination in both countries would be a straightforward extension. The Nash equilibrium of the "world economy" is obtained by maximizing the Nash product in one country, taking the other country as given at the equilibrium value. The analysis could also be extended to parallel policy determination by both countries ending up with Nash equilibrium. While these are relatively straightforward extensions, there are harder issues to solve like the issue of how to provide a theoretical model of biodiversity valuation in a more adequate, but still a tractable way.

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Appendix: Comparative statics of production and timber demand

1. Comparative statics

One can solve the privately optimal production for both coutries to be

A1 $$y^{opt} = \frac{(2\theta - 1)\alpha - 2c + c^*}{4\theta - 1}$$

A2 $$y^{*opt} = \frac{\theta\alpha - 2\theta c^* + c}{4\theta - 1}$$

Their properties are described Table 1 and the homogenous product case can be obtained by setting $\theta = 1$.

Table 1. *Comparative statics of production and timber demand under linear aggregate demand*

Exogenous variable	**Home country**	**Foreign contry**
Domestic timber Price	$y_p = -\frac{2c_p}{4\theta(\overline{m}) - 1} < 0$	$y_p^* = \frac{c_p}{4\theta(\overline{m}) - 1} > 0$
Foreign timber Price	$y_{p^*} = \frac{c_p}{4\theta(\overline{m}) - 1} > 0$	$y_{p^*}^* = -\frac{2\theta(\overline{m})c_p}{4\theta(\overline{m}) - 1} < 0$
Relative "green" Quality parameter	$y_\theta = \frac{2[\alpha + 2(2c - c^*)]}{(4\theta(\vec{m}) - 1)^2} > 0$	$y_\theta^* = -\frac{\alpha + 2(2c - c^*)}{(4\theta(\overline{m}) - 1)^2} < 0$

As for the comparative statics of domestic timber demand, applying Shephard's lemma yields the conditional demand for timber as the derivative of the cost function with respect to timber price: $x = c_p y$. The qualitative properties of timber demand depend on susbtitution and output effects as follows

A3a $$\frac{dx}{dp} = c_{pp} y + y_p c_p < 0$$

A3b $$\frac{dx}{dp^*} = c_p y_{p^*} > 0$$

A3c $$\frac{dx}{d\theta} = c_p y_\theta = y_\theta \frac{x}{y} > 0,$$

where $c_p > 0$ and $c_{pp} = (a - 1)c_p / p < 0$.

2. The effect of $\overline{m}$ on the price elasticity of timber demand

The elasticity of timber demand was defined as $\eta = -\frac{x_p^d p}{x}$. Equation A3a can be written as $x_p = -(1-a)c_p y / p + y_p c_p = c_p \left[y_p - \frac{(1-a)y}{p} \right]$, and by noting that $c_p y / x = 1$, we end up with

A4 $$\eta = -\frac{x_p p}{x} = \left[-\frac{y_p p}{y} + (1-a) \right],$$

where the first term indicates output elasticity and the second term is the substitution elasticity on timber demand of a change in timber price.

By using the comparative statics of Table 1, one obtains for differentiated products

A5 $$\frac{y_p p}{y} = -\frac{2c_p p}{(4\theta - 1)y} < 0$$

and the case of homogeous goods can be obtained by setting $\theta = 1$. Differentiating A5 with respect to $\overline{m}$ gives

A6 $$\eta_{\overline{m}} = -\frac{2c_p p[4\theta'(\overline{m})y + (4\theta(\overline{m}) - 1)y_\theta \theta'(\overline{m})]}{[(4\theta(\overline{m}) - 1)y]^2} \begin{cases} < 0, & if\ \theta'(\overline{m}) > 0 \\ = 0, & if\ \theta'(\overline{m}) = 0 \end{cases},$$

as was argued in the text.

* * * * * *

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