Can Cartelisation Solve the Problem of Tropical Deforestation?

By

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I. The Problem

Tropical deforestation turns out to become one of the most serious global environmental problems of the ending twentieth century.[1] Rain forests are being cleared for the production of timber and for the cultivation of arable land. This has considerable negative side-effects. On the one hand, there are national problems for the countries on whose territories the forests are located; on the other hand, global externalities arise from the public-good character of tropical rain forests.

The national problems are caused by the speed and the large scale on which tropical deforestation takes place. Tropical topsoils are very poor and, therefore, they are exhausted by agriculture very quickly [Sioli, 1987]. If large areas are cleared and topsoils are depleted, the regenerative forces of nature do not suffice to recultivate the forest.

The global impacts of tropical deforestation are twofold. On the one hand, the biomass of tropical rain forests binds a large proportion of the atmospheric carbon. By deforestation this carbon is transformed into carbon dioxide, which accelerates and aggravates the greenhouse effect. Besides the global warming-up, deforestation may cause additional severe climatic changes since it affects the cycle of evaporation and precipitation in the tropics. On the other hand, tropical deforestation is inevitably connected with species extinction. Species most of which have not yet been explored or even are not known yet disappear before their economic potential can be evaluated, and their genetic information is lost.

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[1] For good surveys of the issue of tropical deforestation see Guppy [1984] and Sioli [1987].

For these reasons, it appears to be appropriate to decelerate the process of deforestation drastically and to apply resource-conserving measures. Various kinds of measures are imaginable. In this paper, I want to consider one of them, the cartelisation of timber exports. This proposal is due to Guppy [1983; 1984] and Gillis [1988]. They argue that if the timber-exporting countries do what the oil-exporting countries did in the seventies, namely forming a cartel, this will have a considerable resource-conserving effect and, moreover, the countries will profit from higher prices.

If tropical deforestation were only an agricultural problem, this idea would not make much sense. But forestry indeed plays a central part in the process of deforestation. Not only does the timber industry itself destroy large areas by cutting valuable timber, but it also brakes the path for agriculture by providing the infrastructure (aisles, roads etc.) that makes the forest accessible to squatters.

At a first glance the proposal seems to be supported by economic theory – not only by static monopoly theory but also from a dynamic point of view. Hotelling [1931] in his seminal paper on exhaustible resources has shown that, under some quite general conditions, the rate of extraction is lower under monopoly than under perfect competition. Or as Solow [1974, p. 8] puts it, "the monopolist is the conservationist's friend". The question to be addressed in the following sections is whether this result can be maintained for renewable resources such as tropical rain forests: Can cartelisation save tropical rain forests?

The approach to be chosen for the following analysis is a model of a timber-exporting country. The country exports its timber (or other goods whose production is based on tropical deforestation) and it imports consumption goods from abroad. Domestic consumption of the resource and capital accumulation within the country are not modelled since this would complicate the analysis without providing deeper insights into the issue under consideration. In order to concentrate on the impact of cartelisation, only the market structure will be varied and all other parameters remain unchanged. Thus, two scenarios will be distinguished. In one of them, we look at a representative timber-exporting country acting as a price taker. Perfect futures markets are assumed to exist and to coordinate supply and demand. The other case is the cartel scenario in which supply is monopolistic. To make these two cases comparable, it is assumed that the parameters of the model are the same for the cartel and for the price-taking country.

II. The Model

The following notation will be used: a derivative of a function is represented by a prime, a dot above a variable denotes its derivative with respect to time, t, and a hat its growth rate. The following variables, parameters, and functions will be used:

$N(t)$	size of the tropical rain forests
$q(t)$	timber produced and exported
$c(t)$	consumption
$V(t)$	foreign assets
δ	discount rate
r	interest rate
a	deforestation per unit of timber
$g(N(t))$	regeneration function ($g(0)=0$, $g(N^{\max})=0$, $g''(N(t))<0$, and $N^{\max}>0$)
$k(q(t))$	cost of timber production ($k(0)=0$, $k'(q(t))>0$, $k''(q(t))>0$)
$p(q(t))$	inverse demand function (in units of the imported consumption good) ($p'(q(t))<0$)
$\eta(q(t))$	elasticity of the inverse demand function ($\eta(q(t))=q(t)\,p'(q(t))/p(q(t))$)
$R(q(t))$	profit function ($R(q(t))=q(t)\,p(q(t))-k(q(t))$, $R''(q(t))<0$)
$u(c(t))$	welfare function ($u'(c(t))>0$, $u''(c(t))<0$)

For the sake of a simpler notation, the argument of time-dependent variables will be omitted.

The country is assumed to maximise the present value of future welfare,

$$\int_0^\infty u(c)\exp(-\delta t)\,\mathrm{d}t, \tag{1}$$

subject to the constraints

$$\dot{N}=g(N)-a\,q, \tag{2}$$

$$N(0)=N_0 \quad \text{and} \quad \lim_{t\to\infty} N(t) \geq 0, \tag{3}$$

$$\dot{V}=R(q)-c+rV, \tag{4}$$

$$V(0)=V_0 \quad \text{and} \quad \lim_{t\to\infty} V(t) \geq V_{\min}, \tag{5}$$

with respect to the control variables c and q. Equations (2) and (3) represent the natural-resources constraint. This is the standard specification of a renewable-resources allocation problem (see Plourde [1970] and Clark [1976]). The intertemporal budget constraint is given by (4) and (5). Equation (4) is the balance-of-payments equation. According to (5), foreign borrowing is constrained in the long run such that the budget constraint binds.

III. Optimality Conditions

The Hamiltonian of this problem is

$$H=u(c)+x\{g(N)-aq\}+y\{R(q)-c+rV\}, \tag{6}$$

where x and y are the costate variables or the shadow prices of the rain forest and foreign assets, respectively. They change according to

$$\dot{x}=(\delta-g')\,x \quad \text{and} \tag{7}$$

$$\dot{y}=(\delta-r)\,y. \tag{8}$$

Differentiation of H with respect to c and q gives the necessary optimality conditions

$$u'=y \quad \text{and} \tag{9}$$

$$R'=ax/y. \tag{10}$$

Since the Hamiltonian is concave in (c, q, V, N), these conditions are also sufficient for an optimum. Equation (9) is Ramsey's rule of optimum saving. The shadow price of foreign assets, y, is positive since marginal utility is always positive. The shadow price of the rain forest, x, is positive, too; an increase in the resource endowment yields an increase in exports and, therefore, an increase in consumption, which is welfare-improving. The positive shadow price constitutes a scarcity rent.

Since the capital market is perfect in this model, Fisher's separation theorem applies and production decisions are not affected by the consumption-versus-saving decision. Therefore, the time paths of the felling rate and the stock of tropical rain forest can be analysed independently of the paths of consumption and asset accumulation.[2] Combining (7), (8) and (10) yields:

$$\hat{R}'(q) = r - g'. \tag{11}$$

This is the condition for the optimum rate of timber production. It depends on the interest rate and the rate of regeneration. Marginal profits are positive since the intertemporal user costs of the rain forest are taken into account.

The system is in equilibrium when user costs, the felling rate, and the stock of forest are constant. Let equilibrium values be represented by asterisks. Then

$$g'(N^*) = r \quad \text{for} \quad \dot{q} = 0, \tag{12}$$

$$a\,q^* = g(N^*) \quad \text{for} \quad \dot{N} = 0. \tag{13}$$

Equation (12) defines the equilibrium state of nature.[3] The marginal rate of regeneration equals the interest rate.[4] This is an arbitrage condition. It states that all stores of wealth should yield the same rate of return in the equilibrium. One of them is the stock of foreign assets, yielding the market rate of interest. The other one is the renewable resource, and its rate of return is the regeneration rate of its last unit. The corresponding rate of extraction is determined by condition (13). As in other models of optimum resource use (see Plourde [1970] and Clark [1976), Ch. 4.2.] the extraction rate is below the maximum-sustainable-yield rate. Since the equilibrium is determined completely by the interest rate and some technical and biological parameters, the following conclusion has to be drawn:

Proposition 1

The equilibrium (q^*, N^*) is independent of the structure of the timber market.

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[2] The consumption path can easily be derived from (8) and (9). The growth rate of consumption depends on the interest rate, the rate of discount, and the elasticity of marginal utility.

[3] We assume that there exists a positive N^* such that condition (12) is satisfied.

[4] In the standard model, without capital markets, the equilibrium would be determined by the time preference rate instead of the rate of interest. The interest-rate result has also been obtained by Dasgupta et al. [1978] for the case of exhaustible resources.

IV. The Impact of Market Structure

In order to analyse the impact of market structure on the optimum solution, the dynamic behaviour of the optimum path will be analysed. This path is determined by the state equation, (2), and the optimality condition, (11). From (2) it follows that the tropical forest shrinks if the rate of deforestation, aq, is relatively high; it grows if q is smaller than its equilibrium value q^*. Rewriting (11) yields

$$\dot{q} = (r - g')(R'/R''). \tag{14}$$

Since R' is positive and R'' is negative, $\dot{q}$ is negative for large values of N, positive for small values of N, and zero if $g'(N^*) = r$. Using these results, the optimum solution can be represented graphically in a (q, N) phase space (see Figure 1). The equilibrium is a saddle point, and the saddle path is positively sloped. Thus, the initial rate of deforestation chosen in the optimum will be high if the initial state of nature is good (i.e. if N_0 is large) and vice versa.

This result is not new; it has already been established by Plourde [1970] in a similar model. The effects of the change in market structure can now be derived as follows:

(*i*) The state equation is not affected by the change in the market structure. This implies that the horizontal component of motion in the phase space, $\dot{N}$, remains unchanged.

(*ii*) The vertical component $\dot{q}$, however, is affected by the market structure since it depends on the first and second-order derivatives of the profit function. For a given value of N, the change in q is the more vigorous the larger the absolute value of R'/R''.

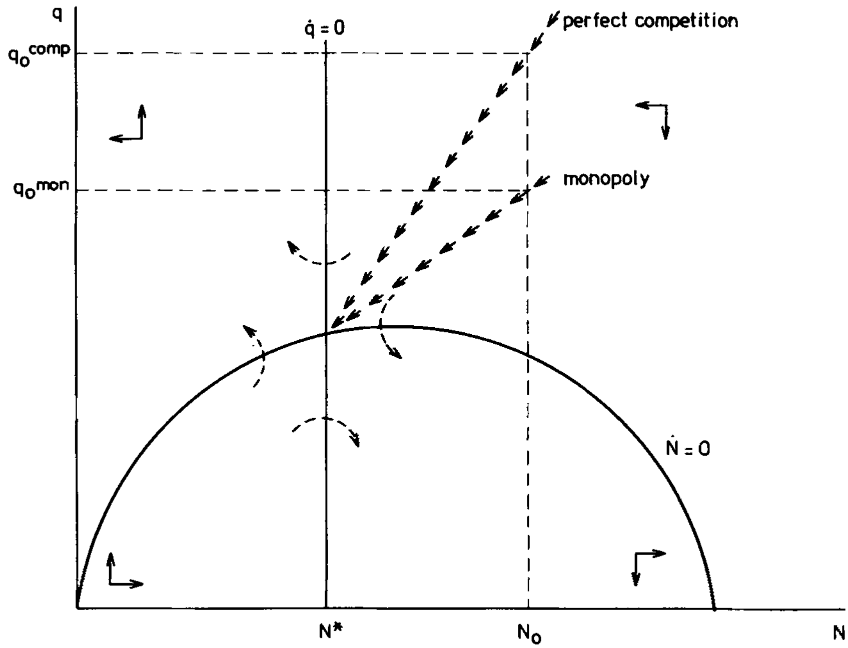
(*iii*) With an unchanged horizontal component and a stronger vertical component, the new saddle path must be steeper than the former saddle path. All paths starting from the former saddle path are now unstable since the vertical component dominates the horizontal component. An exact proof is given in the appendix.

(*iv*) It is also shown in the appendix that the absolute value of R'/R'' is larger in the competitive than in the non-competitive case if the elasticity of demand is a non-decreasing function of the price. This implies:

Proposition 2

If the elasticity of demand is a non-decreasing function of the price (or equivalently, $\eta'(q) \leq 0$), then the competitive path is steeper than the monopolist's path.

Figure 1 – *Saddle Paths for Different Market Structures*



$\eta'(q) \leq 0$ is a sufficient condition; even if it is not satisfied, the competitive path may still be steeper than the monopolist's path. A condition which is necessary and sufficient is given by inequality (A 8) in the appendix. The condition $\eta'(q) \leq 0$ includes many widely-used types of demand functions, e.g. constant-elasticity as well as linear demand functions.

The implication of this proposition can be derived from the graphical representation in Figure 1. Given the initial state of nature, N_0, the initial rate of felling is higher in the competitive than in the monopolistic case. In the long run, however, both saddle paths converge to the same equilibrium. Thus, the resource-conserving effect of the cartelisation is only a short-term effect.

V. Final Remarks

The central result of this paper can be summarised as follows: The monopolist is indeed the conservationist's friend – but only in the short run. In the long run, the monopolistic solution does not differ from the competitive one. Therefore, the formation of an Organisation of Timber Exporting Countries will not solve the problem of tropical deforestation. Nonetheless, there could be some resource-conserving side-effects of a cartelisation if intertemporal restrictions were taken into account more explicitly by a monopolist than by competitive suppliers, but this would be a result of a change in preferences rather than of the change in the market structure.

How can then a solution to the problem of tropical deforestation look like? If it is in the global interest that some countries conserve their rain forests, the global community should compensate these countries for foregone gains from trade. Assume the timber-exporting country obtains a compensation payment of φN. Then the balance-of-payments equation is augmented by this term. Applying the maximum principle to this problem, yields an equilibrium value of N which is determined by

$$g'(N^*) = r - a\varphi/R'(q^*).$$

It follows that the equilibrium state of nature can be improved by increasing φ. Moreover, it can be seen that this long-run solution will depend on the market structure. If the equilibrium is unique, then N^* is larger in the monopolistic than in the competitive case. Hence, in a model with stock-dependent transfer payments, the cartelisation of tropical timber supply has a resource-conserving effect even in the long run.

Appendix

In order to examine the properties of this system of differential equations, it is linearised in the equilibrium.

$$\dot{N} = r(N - N^*) - a(q - q^*), \tag{A1}$$

$$\dot{q} = -g'' R'/R'' (N - N^*). \tag{A2}$$

The linearised system is a good approximation of the original system in a close neighbourhood of the equilibrium. In a phase space exhibiting saddle-point stability, there are only two linear paths, the saddle path itself and the unstable manifold to which all other paths converge asymptotically. Therefore, the slope of the saddle path, z, can be determined by using $q - q^* = z(N - N^*)$ in (A1) and (A2):

$$z\dot{N} = rz(N - N^*) - az^2(N - N^*), \tag{A3}$$

$$z\dot{N} = -g'' R'/R'' (N - N^*). \tag{A4}$$

It follows that $a z^2 - r z - g'' R'/R'' = 0$ and

$$z_{1,2} = \tfrac{1}{2} r/a \pm \sqrt{\tfrac{1}{4}(r/a)^2 + g'' R'/(a R'')}. \tag{A5}$$

There are two solutions for z. The positive solution is the slope of the saddle path; the negative solution characterises the linear unstable path to which all unstable solutions converge in the long run. The slope of the saddle path is decreasing in R'/R''.

R'/R'' depends on the market structure. The competitive supplier takes the price as given whereas the monopolist takes the demand function into account. Therefore:

$$\frac{R'}{R''} = \frac{p - k'}{p' - k''} \quad \text{for perfect competition,} \tag{A6}$$

$$\frac{R'}{R''} = \frac{(1+\eta)\, p - k'}{(1+\eta)\, p' + p\eta' - k''} \quad \text{for the monopolist.} \tag{A7}$$

Assume that R'/R'' is smaller in the competitive case. Then

$$(p - k')/(p' - k'') < [(1+\eta)\, p - k']/[(1+\eta)\, p' + p\eta' - k''].$$

This can be rearranged such that

$$(p - k')\, p\eta' < p'\eta\, k' - \eta\, p\, k''. \tag{A8}$$

Since the right-hand side of this inequality is unambiguously positive, $\eta'(q) \leq 0$ is a sufficient condition for the saddle path to be steeper in the competitive than in the monopolistic situation. Proposition 2 then follows from the fact that the price elasticity of demand is η^{-1}.

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