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von

Peter Welzel

Beitrag Nr. 82 Dezember 1992

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Oligopolistic Tragedies

National Governments and the Exploitation of International Common Property

Peter Welzel
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December 1992

A n

Abstract

In this paper a standard two–stage oligpoly game is used to work out the economics and politics of international common property. In stage 1, governments which host firms using the commons decide on optimal input taxes. In stage 2, profit maximizing firms choose the level of a variable input. Private decisions in this stage imply the well-known overexploitation of the commons which is reduced if there is cross–ownership among the user firms. The "tragedy of the commons" is further aggrevated, however, by the policy decisions of welfare maximizing governments in stage 1, since governments have incentives to implement policies to shift rents from foreign to domestic firms. Coordination of tax policies, retaliatory mechanisms in situations of repeated interaction, and international firm ownership are discussed as potential solutions to this twofold problem of the commons.

Keywords: international common property, rent–shifting, policy coordination

JEL–classification: D62, H23, L13

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1 Introduction

One of the oldest externality discussed in the economics literature is the case of cattle grazing on unfenced ("common") land. If there is more than one owner to the livestock, the common property will be overutilized relative to the first best solution designed by a monopolist or a social planer. This situation is usually called a "problem of the commons" or, more dramatically, a "tragedy of the commons". Analytically, a scarce fixed factor ("land") does not receive a rent. It is overexploited by private economic agents who tend to equate the average instead of the marginal product of a variable input ("cattle") to the rental rate of this input (cf. *Weitzman 1974, p. 225*). An individual agent does not take into account the negative external effect which his own use of the common property causes for the rest of the users.

The problem of the commons can readily serve as a prototype for similar situations with a nonexcludable common property such as the use of a fishing ground, an oil reserve, a park or a hunting ground. It was discussed and analyzed among others by *Hardin (1968)*, *Haveman (1973)* and *Weitzman (1974)*. For the case of binary choices *Schelling (1973)* provided an interpretation as a "multi-person prisoners' dilemma". More recently, *Cornes/Sandler (1983)* introduced oligopoly-like reaction functions and the notion of conjectures into the analysis of the commons.

In this paper I want to focus my attention on common property resources which are outside any national jurisdiction. A large number of today's most pressing environmental problems seem to fit this description. The setup is characterized by the absence of a single government holding the power to assign property rights to the use of the commons. Instead, there are two or more governments each of which can only influence part of the users of the commons. My analysis sets out from the specification of *Cornes/Sandler (1983)* and extends the use of oligopoly theory as a tool for thinking about the problem of the commons to the kind of two-stage model familiar from industrial economics. Whereas *Cornes/Sandler* were primarily concerned with the properties of oligopoly equilibria under different conjectures, I shall ask whether governments which are hosts to the oligopolistic users can and will improve resource allocation with a tax or subsidy on the variable input as policy instrument. The results point to the uncomfortable fact that governments acting rationally to maximize national welfare will tend to increase instead of decrease the problem of the commons. I shall then proceed to consider ways that help national governments to escape from the collectively irrational outcome of interacting policies. The paper is organized as follows: In section 2 the basic *Cournot* oligopoly model for a commons is briefly reviewed and extended to the case when firms hold equity interests in each other. Section 3 deals with policy decisions for a common property outside the jurisdiction of national governments. In section 4 I examine mechanisms rational governments can implement to induce efficient exploitation of the common property. Section 5 sums up.

2 Oligopoly Approach to the Commons

Cornes/Sandler (1983) specified the problem of the commons in a simple framework which allows for the use of oligopoly theory. Assume there is a common fishing ground of given size. The total catch X depends on the number of vessels operating, i.e., on the size of the total fleet V. There are diminishing returns to fleet size. This is expressed by a production function

$$X = F(V), \qquad F' > 0, \quad F'' < 0, \quad F(0) = 0, \quad \lim_{V \to 0} F'(V) = \infty. \tag{1}$$

Under our assumptions the average product is greater than the marginal product, i.e., $F(V)/V > F'(V)$. The price of one unit of output is 1, while that of the variable input is p. To focus on the efficient use of the commons and exclude other effects, both prices are assumed to be constant. Aggregate output X is produced by n producers. Individual production functions can be written as

$$x_i = f\left(v_i, V_{-i}\right), \qquad i = 1, \ldots, n. \tag{2}$$

v_i is producer i's input of the variable factor. V_{-i} is the aggregated input of all producers $j \neq i$, i.e., $V_{-i} = \sum_{j=1}^{n} v_j - v_i = V - v_i$. More specifically, assume that each firm's share of total output equals its share of the variable input. This implies

$$x_i = \frac{v_i}{v_i + V_{-i}} F\left(v_i + V_{-i}\right) = \frac{v_i}{V} F(V). \tag{3}$$

Consider first for future reference the solution a social planer or a monopolist who owns all the vessels would implement. Solving

$$\max_{V} \quad F(V) - pV \tag{4}$$

leads to the first order condition

$$F' \stackrel{!}{=} p. \tag{5}$$

This implies an optimal fleet size V^* which is independent of the distribution of $v_1, \ldots, v_n$. For an illustration of this result in (v_i, V_{-i})-space note that in the optimum

$$\left.\frac{dV_{-i}}{dv_i}\right|_{F'=p} = -1. \tag{6}$$

The set of *Pareto*–optimal allocations $\left(v_i^P, V_{-i}^P\right), v_i^P + V_{-i}^P = V^*$, is given in figure 1 by a line PP with slope -1.

Suppose now the individual firms choose their variable inputs independently in a *Cournot–Nash* game. Each producer solves

$$\max_{v_i} \quad \pi_i \quad = \quad \max_{v_i} \quad f\left(v_i, V_{-i}\right) - pv_i. \tag{7}$$

The first order conditions

$$f_{v_i} \stackrel{!}{=} p \tag{8}$$

imply that the resource allocation will equal the first best situation if and only if $V_{-i} = 0$, i.e., if there is a monopoly.

(8) implicitly defines producer i's reaction function $v_i\left(V_{-i}\right)$. For the slope of the reaction curve in (v_i, V_{-i})–space we get

$$\left.\frac{dV_{-i}}{dv_i}\right|_{f_{v_i}=p} = -\frac{f_{v_i v_i}}{f_{v_i V_{-i}}}. \tag{9}$$

Given the technology (3), we find $f_{v_i v_i} < f_{v_i V_{-i}} < 0$ which implies a slope of less than -1 for the reaction curve, i.e., it is steeper than the line of *Pareto* optima. Considering

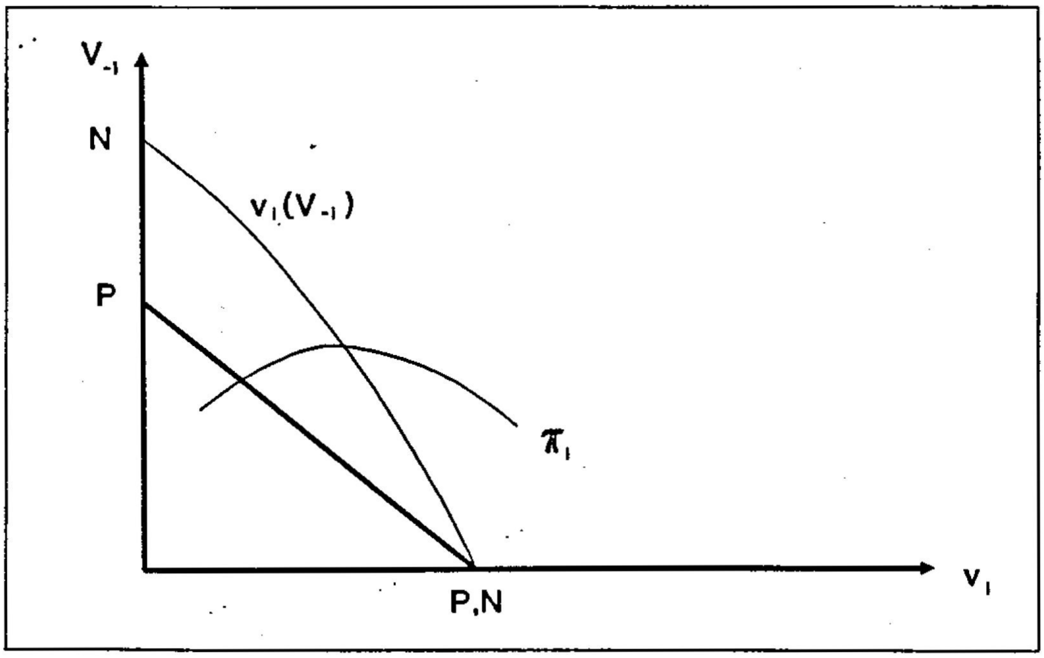

Figure 1: *Cournot–Nash* and *Pareto* equilibria

producer i's isoprofit contours we get a slope of

$$\left.\frac{dV_{-i}}{dv_i}\right|_{\pi_i=const.} = -\frac{f_{v_i} - p}{f_{V_{-i}}}. \tag{10}$$

The reaction curve given by (8) connects the maxima of i's isoprofit contours. Lower contours correspond to higher profit levels. To summarize consider figure 1 in (v_i, V_{-i})–space (cf. *Cornes/Sandler 1983, p. 788*). PP depicts the locus of *Pareto*–optimal allocations, NN the locus of equilibria of the *Cournot–Nash* game, and π_i an isoprofit contour of producer i. For $n > 1$ the solution of the *Cournot–Nash* game is socially inferior to the first best solution.[1] The reason for this inefficient outcome of private decisions is readily identified. Whereas producer i takes into account the private marginal product

$$\frac{\partial f(v_i, V_{-i})}{\partial v_i} = f_{v_i} = \frac{V_{-i}}{V}\left(\frac{F}{V} - F'\right) + F' > 0 \tag{11}$$

of his input decision, he neglects the external effect on producer j, which is given by

$$\frac{\partial f(v_j, V_{-j})}{\partial v_i} = f_{V_{-j}} = \frac{v_j}{V}\left(F' - \frac{F}{V}\right) < 0. \tag{12}$$

The total externality caused by firm i's behavior can then be written as

$$\sum_{j \neq i} \frac{\partial f(v_j, V_{-j})}{\partial v_i} = \frac{V_{-i}}{V}\left(F' - \frac{F}{V}\right). \tag{13}$$

Consider the case $n = 2$ which can be illustrated in (v_1, v_2)–space. Figure 2 exhibits reaction curves $v_1(V_{-1})$ and $v_2(V_{-2})$ for firm 1 and 2, respectively. (3) guarantees a steeper reaction curve for firm 1 and stability of the equilibrium. The *Cournot–Nash* equilibrium is found at the intersection C. From the corresponding isoprofit contours π_1^C and π_2^C we see that there is scope for a *Pareto* improvement by switching to an allocation in the region ABC. In particular, the line segment AB contains *Pareto* optima which are *Pareto*–superior to the *Cournot–Nash* solution. However, if producers 1 and 2 come up with an agreement to choose an allocation on AB, there is an incentive for both of them to deviate from this cooperative solution. If, for example, they agreed on allocation D, firm

[1] *Cornes/Sandler (1983)* pointed to the more general case of conjectural variations which can be used as proxies to model different kinds of oligopolistic interaction. The problem of the commons is reduced, if firms expect their competitors to move in the same direction. Collusion among firms increases efficiency as far as using the common property is concerned. Note, however, that the assumption of a given output price does not allow inefficiencies arising from increased monopoly power to show up in our analysis. If, on the other hand, firms expect their competitors to move in the opposite direction, a larger value of v_i is optimal, i's reaction curve is shifted to the right, and the problem of the commons is increased.

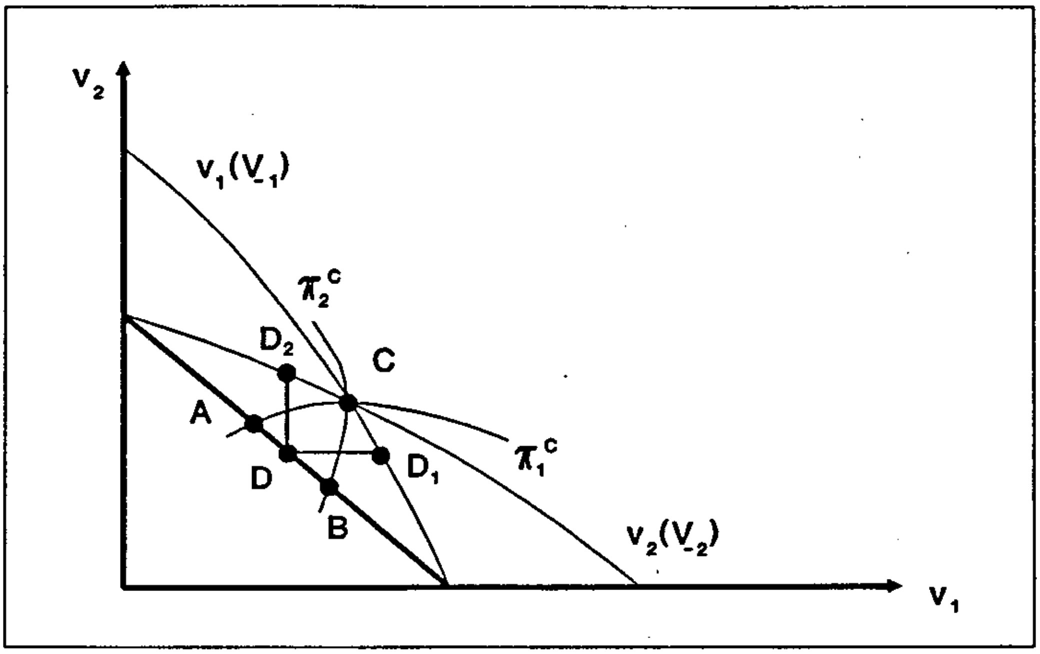

Figure 2: *Cournot–Nash* and *Pareto* equilibria for $n = 2$

1 will prefer D_1 and firm 2 will prefer D_2 given the competitor sticks to the agreement. Imagine that when deciding on the use of the common property, the producers can choose among two possible actions which can be termed "cooperative" and "non-cooperative". "Cooperative" means that producer i sticks to the input choice which corresponds to point D in figure 2. "Non-cooperative", on the other hand, implies that i behaves according to his reaction function $v_i(V_{-i})$. For example, outcome D1 is reached, when firm 1 acts non-cooperatively whereas firm 2 behaves in the cooperative way. The payoffs resulting from this game are ranked as follows:

$$\pi_1(D_1) > \pi_1(D) > \pi_1(C) > \pi_1(D_2), \tag{14}$$

$$\pi_2(D_2) > \pi_2(D) > \pi_2(C) > \pi_2(D_1). \tag{15}$$

"Non-cooperative" is a dominant strategy for each firm. The competitors therefore face a prisoners' dilemma situation. Individual rationality will not lead them to a collectively rational, i.e., *Pareto*-optimal, outcome. Analogously, $n > 2$ firms face a n-person prisoners' dilemma in the sense of *Schelling (1973)*.

Before looking at government intervention in this oligopoly exploiting an international common property, consider briefly the possibility that producers are linked through cross ownership. In fact, in today's world of joint ventures and strategic alliances we can expect at least some of the firms to hold equity interests in their competitors. From the work of *Reynolds/Snapp (1986)* in industrial economics we know that the outcome of *Cournot* oligopolies becomes more collusive when equity interests among competing firms are increased. Holding a stake in a competitor induces an oligopolist to "internalize" some of the "external" effect he imposes on the industry.

Adopting this idea to the oligopoly model of a commons, it is straightforward to show that cross ownership among the users will reduce the degree of overexploitation of the common property. Denote by $e_{ij}, i \neq j$, producer i's ownership interest in firm j, and by $e_{ji}, i \neq j$, producer j's ownership interest in firm i. The firm maximization problem (7) has to be re-defined as

$$\max_{v_i} \quad \left(1 - \sum_{j \neq i} e_{ji}\right) \left(f\left(v_i, V_{-i}\right) - pv_i\right) + \sum_{j \neq i} e_{ij} \left(f\left(v_j, V_{-j}\right) - pv_j\right). \tag{16}$$

Note that the maximization problem is specified such that i maximizes his profit net of the share $\sum_{j \neq i} e_{ji}$ paid to competitors holding a stake in firm i. This implies that producers $j, j \neq i$, only hold non-controlling shares in firm i. Changing this assumption by dropping the e_{ji} terms in (16) does not change the basic effects of cross ownership. It does, however, reduce the magnitude of these effects. Maximization yields first order conditions

$$\left(1 - \sum_{j \neq i} e_{ji}\right) \left(f_{v_i} - p\right) + \sum_{j \neq i} e_{ij} f_{V_{-j}} \stackrel{!}{=} 0. \tag{17}$$

From comparison with (8) and (12) it is apparent that producer i partially internalizes his negative external effect on j as long as $e_{ij} \neq 0$, i.e. as long as i holds an ownership share in j.

Given (17), the two main results from *Reynolds/Snapp (1986)* are readily verified for the model used here. Implicit differentiation yields the following effects of changes in ownership structure on optimal behavior:

$$\frac{\partial v_i}{\partial e_{ij}} = -\left(\left(1 - \sum_{j \neq i} e_{ji}\right) f_{v_i v_i} + \sum_{j \neq i} e_{ij} f_{V_{-j} v_i}\right)^{-1} \cdot f_{V_{-j}}, \tag{18}$$

$$\frac{\partial v_i}{\partial e_{ji}} = -\left(\left(1 - \sum_{j \neq i} e_{ji}\right) f_{v_i v_i} + \sum_{j \neq i} e_{ij} f_{V_{-j} v_i}\right)^{-1} \cdot \left(-\left(f_{v_i} - p\right)\right). \tag{19}$$

While the sign of $f_{V_{-j} v_i}$ is generally indeterminate, it is positive for absolute values of F'' being not too small. Using this assumption which amounts to saying that the problem of the commons is rather severe, the signs in (18) and (19) are unambiguously given as

$$\frac{\partial v_i}{\partial e_{ij}} < 0, \qquad \frac{\partial v_i}{\partial e_{ji}} \leq 0. \tag{20}$$

If firm i increases its share in firm j, its optimal use of the common property resource decreases. Drawing on (17) to determine the sign of $f_{v_i} - p$, it can also be said that an increase in firm j's share in i induces i to use less of the input as long as i has interests in at least one of its rival firms.

To use these results, consider a change from one ownership structure to another where e_{ij} increases and all other shares remain constant. Producer i will reduce v_i, and producer j will reduce v_j, if at least one share $e_{jk} \neq 0, k \neq j$. Both firms i and j lower their utilization of the commons. Their reaction curves are shifted to the left. In equilibrium, firms $k, k \neq i, j$, whose ownership shares do not change and whose reaction curves are not shifted, will increase their inputs v_k. Since the sum of these increases is lower than the aggregate reduction of firms i and j, an increase of ownership links between firms i and j reduces the problem of the commons. As *Reynolds/Snapp (1986)* point out on the basis of numerical examples for their model, the contractive effects of cross ownership can be considerable even for small ownership shares. Furthermore, ownership increases involving big firms will be more contractive.

A look at figure 2 suggests that there could even be ownership structures which lead to a socially optimal outcome of the oligopoly game by shifting the reaction curves to the left such that they intersect on the line of *Pareto* equilibria. Following *Reynolds/Snapp (1986)* for the special case of symmetric firms, one such ownership structure is readily identified. Assume there are n identical firms, and all e_{ij} take the value of $1/n$. First order conditions (17) then reduce to

$$f_{v_i} - p + (n-1) f_{V_{-j}} \stackrel{!}{=} 0. \tag{21}$$

Substituting from (11) and (12) and using symmetry yields $F' \stackrel{!}{=} p$, i.e. the oligopolistic interaction leads to an efficient utilization of the commons.

In this section competition among oligopolistic users of a common property resource was seen to generate overexploitation. Partial equity interests among the oligopolists reduce this inefficiency. In the tradition of *Coase (1960)* one might expect or hope for a market solution to the problem of the commons: There is an incentive for firms to acquire equity interests in each other. However, transaction costs which can be expected to play a role in the international framework used here will impede this solution. In addition, free–rider problems can work against the *Coasian* solution: In the case of $n > 2$ all firms $k \neq i, j$ benefit from cross ownership among firms i and j. Given that markets will probably not generate the optimal outcome, we should then ask what government(s) can do about the inefficient utilization of international common property.

3 Rational Governments and the Use of International Common Property

Suppose there are several governments, each of which can influence at least one of the producers using the common property. This is the situation of fishing or seabed mining in international waters which lie outside the limits of any nation's jurisdiction. The policy instrument under consideration is a tax or subsidy on variable inputs. Questions of interest in this setup are:

- Can a single government use its policy instrument to reduce the overutilization of the commons? Will a welfare–maximizing government implement such a policy?
- Will a *Cournot–Nash* game among policy–setting governments reduce or increase the problem of the commons?

To examine these issues, assume there are $m = 2$ countries each of which hosts one producer. Generalizations to $m > 2$ governments and $n \geq m$ producers are straightforward. Producers play a *Cournot* game in inputs. Partial equity interests are excluded for the sake of simplicity. Suppose government 1 uses a (positive or negative) per unit input tax t_1, while government 2 does not use the policy instrument. Firm 1 which is located in country 1 now solves

$$\max_{v_1} \quad \pi_1(v_1, V_{-1}, t_1) \quad = \quad \max_{v_1} \quad f(v_1, V_{-1}) - (p + t_1)\, v_1 \tag{22}$$

which yields

$$f_{v_1} \stackrel{!}{=} p + t_1. \tag{23}$$

Given $f_{v_1} > 0$ and $f_{v_1 v_1} < 0$, an increase in t_1 reduces the profit–maximizing value of v_1. A tax (subsidy) on the use of the variable input shifts firm 1's reaction curve to the left (right). Performing the usual comparative–static exercises we find the following effects of changes in t_1 on the equilibrium values of v_1 and v_2:[2]

$$\frac{dv_1}{dt_1} = \frac{f_{v_2 v_2}}{\Delta} < 0, \qquad \frac{dv_2}{dt_1} = -\frac{f_{v_2 V_{-2}}}{\Delta} > 0, \tag{24}$$

where $\Delta = f_{v_1 v_1} f_{v_2 v_2} - f_{v_1 V_{-1}} f_{v_2 V_{-2}} > 0$ due to the second order condition of profit maximization and our assumptions on the technology. If government 1 introduces a tax

[2]Some care with the notation is required: f_{v_i} and $f_{v_i v_i}$ denote the first and the second order partial derivative of firm i's production function with respect to its own input choice. $f_{V_{-i}}$ and $f_{V_{-i} V_{-i}}$ denote the first and the second order partial derivative of firm i's production function with respect to the input choice of its competitor. $f_{v_i V_{-i}}$ and $f_{V_{-i} v_i}$ are cross–derivatives.

($t_1 > 0$), firm 1 reduces and firm 2 increases its input and its use of the common property. For the net effect on $V = v_1 + v_2$ calculate

$$\frac{dV}{dt_1} = \frac{f_{v_2 v_2} - f_{v_2 V_{-2}}}{\Delta} < 0. \tag{25}$$

The introduction or an increase of an input tax by government 1 reduces total input V, i.e., there is a reduction in the overexploitation of the common property. However, as can be seen from (24) taxing firm 1's input benefits the foreign firm 2 and worsens the position of the domestic firm 1. Therefore, a rational welfare-maximizing government will not be inclined to implement a tax policy which improves the use of the common property from an allocative point of view. Instead, there is an incentive for government 1 to implement the opposite policy. Consider government 1's welfare maximization problem in this partial equilibrium model as

$$\max_{t_1} \quad w_1 \quad = \quad \max_{t_1} \quad \pi_1(v_1, V_{-1}, t_1) + t_1 v_1. \tag{26}$$

Assuming that the government credibly announces its policy before the firms make their input decisions, we can use firm 1's first order condition to arrive at the following condition for welfare maximization

$$\frac{\partial \pi_1}{\partial V_{-1}} \frac{dV_{-1}}{dt_1} + t_1 \frac{dv_1}{dt_1} \stackrel{!}{=} 0, \tag{27}$$

which implies an optimal policy of

$$t_1^* = f_{V_{-1}} \frac{f_{v_2 V_{-2}}}{f_{v_2 v_2}} < 0. \tag{28}$$

Note that the fraction involved is just the absolute value of the slope of producer 2's reaction curve, i.e., it measures 2's equilibrium response to marginal changes in v_1. A rational government 1 maximizing national welfare uses an input subsidy instead of an input tax. Announcing this policy will induce firm 1 to behave more aggressively on the commons. While firm 2's input decreases, firm 1 more than compensates for this change and the problem of overexploiting the common property is increased.

Consider figure 3 for an illustration of this line of thought which parallels a result familiar from strategic trade policy (cf. *Brander/Spencer 1985*). By paying an input subsidy government 1 shifts its producer's reaction curve to the right. Point S_1 is the new equilibrium delivering the highest welfare level for country 1 which is compatible with firm 2's behavior given by $v_2(V_{-2})$.[3] Firm 1 is moved to a position of "as-if" *Stackelberg* leadership, i.e., due to the subsidy it behaves as if it were *Stackelberg* leader on a commons

[3]Given (26) and (22), the isoprofit contours of the previous figures can now be interpreted as isowelfare contours.

without a government subsidy. The problem of the commons is aggravated by strategic interaction among the users which creates an incentive for a single government to alter the oligopolist's game. A rational government will give in to this incentive, improving the position of its own producer, damaging foreign firms, and, most importantly, increasing the overexploitation of the common property.

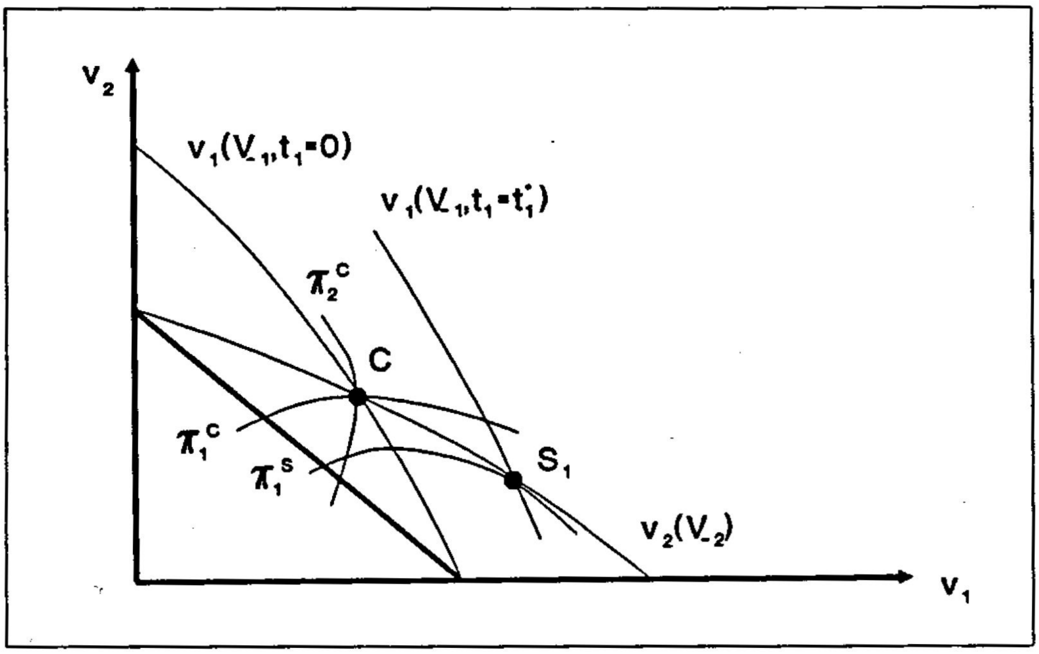

Figure 3: Government 1's optimal policy

Consider now the second question about public policy with several governments exercising jurisdiction over the commons. How will the utilization of the common property be affected, if both governments use their policy instrument? The governments choose t_1 and t_2 in a *Cournot-Nash* game prior to the firms' decisions on v_1 and v_2. The results previously derived imply that both governments have the same incentive to introduce a subsidy. Optimal policies are given by

$$t_1^* = -f_{V_{-1}} \frac{dv_2}{dv_1} = f_{V_{-1}} \frac{f_{v_2 V_{-2}}}{f_{v_2 v_2}} < 0, \qquad t_2^* = -f_{V_{-2}} \frac{dv_1}{dv_2} = f_{V_{-2}} \frac{f_{v_1 V_{-1}}}{f_{v_1 v_1}} < 0, \tag{29}$$

which must hold simultaneously. In figure 4 governments choose their subsidies such that in the equilibrium point S each oligopolistic users' reaction curve is tangent to the other country's isowelfare contour.

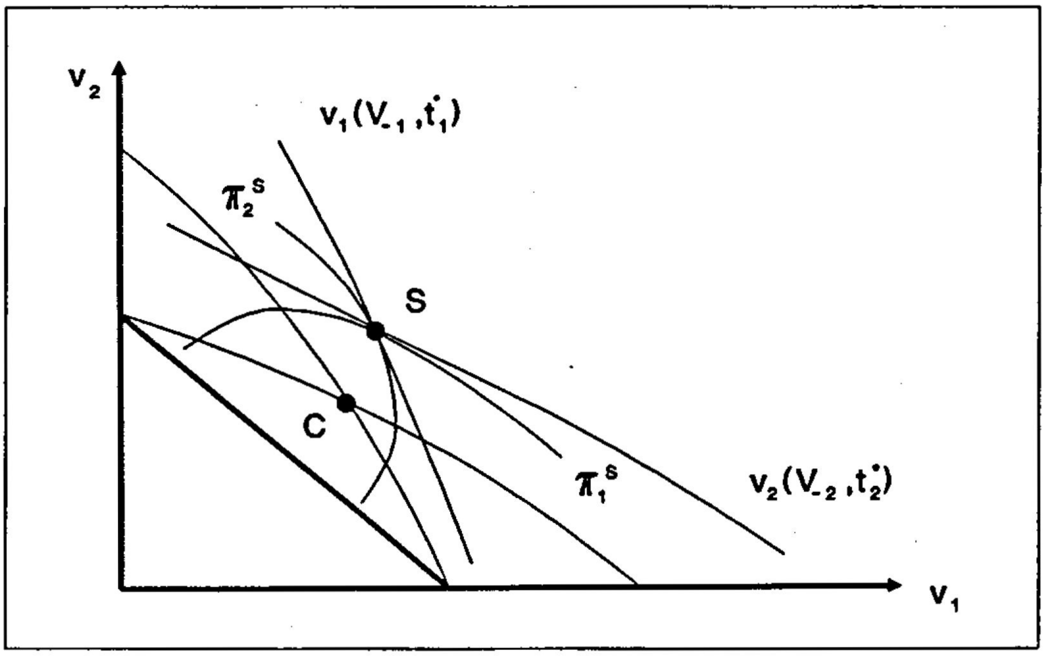

Figure 4: *Cournot–Nash* game among governments 1 and 2

As long as there is not too much difference among the user firms, S is *Pareto*–inferior to point C, where both governments refrain from policy intervention.[4] With two active governments overexploitation of the commons is increased compared to the private equilibrium, since both goverments try to increase national welfare by paying a subsidy to alter the users' game in favor of the national firm.[5]

This section pointed to the fact that governments hosting oligopolistic users of an international common property will implement policies which increase rather than reduce the problem of the commons. In the following I shall examine ways for governments to design policies which avoid this collectively irrational outcome.

[4]With the user firms differing strongly, one — but not both! — producer can be better off in S than in C.

[5]Examining policy decisions when firms hold non–zero conjectures leads to results familiar from two–stage oligopoly games (cf. *Dixit 1986, Eaton/Grossman 1986*). The difference between a firm's actual response and the response conjectured by its competitors determines the sign of the optimal policy. If one is willing to accept conjectures as proxies for different kinds of oligopolistic interaction, the analysis points to the fact that the conjectures held by oligopolistic users of a commons are relevant for the degree of misallocation for two reasons: They influence equilibrium inputs in the producers' game, as *Cornes/Sandler (1983)* first showed, and they influence the policies which rational welfare maximizing governments impose on the producers.

4 International Coordination for an Efficient Use of Common Property

4.1 Coordination of Tax Policies

Governments which hold the power to influence oligopolistic users of an international common property face a dilemma. If they all behave as rational maximizers of national welfare, they will end up at *Pareto*–inferior welfare levels. On the other hand, by imposing suitable tax rates t_i, the governments could induce the producers to make input choices that yield an efficient use of the commons.

Suppose at this point, governments can write an enforcable contract committing themselves to tax policies. If they act cooperatively in determining jointly optimal tax rates $\hat{t}_i$, they maximize the sum of national welfare levels w_1 and w_2, i.e.

$$\max_{t_1,t_2} \quad \pi_1(v_1, V_{-1}, t_1) + t_1 v_1 + \pi_2(v_2, V_{-2}) + t_2 v_2. \tag{30}$$

Using $\partial \pi_i / \partial v_i = 0$ from the producers' maximization and solving the two first order conditions implies

$$\hat{t}_1 \stackrel{!}{=} -f_{V_{-2}} > 0, \qquad \hat{t}_2 \stackrel{!}{=} -f_{V_{-1}} > 0. \tag{31}$$

The optimal tax $\hat{t}_i$ which now accounts for the external effect caused by firm i's behavior is positive. Note that conditions (31) are not yet fully solved. To calculate the tax rates, we would have to use (12) and the additional condition that the allocation be *Pareto*–optimal, i.e. $v_1^P + v_2^P = V^*$.

Recall figure 2 for the intuition of finding optimal tax rates. For the oligopoly game to reach a *Pareto*–optimal allocation, both reaction curves have to be shifted to the left such that they intersect on the line of *Pareto* optima.[6] Appropriately chosen input taxes t_i will cause these shifts. However, there is an infinite number of (t_1, t_2)–combinations leading to (v_1, v_2) such that $v_1 + v_2 = V^*$. Suppose, the governments agree on one particular *Pareto*–optimal allocation $\left(v_1^P, v_2^P\right), v_1^P + v_2^P = V^*$, which can be represented by a point like P in figure 5. This choice may result from a bargaining process or from distributional considerations, expressed for example by a (supra–national) welfare function based on a generalized *Nash* criterion using the non–cooperative *Cournot–Nash* inputs as point of reference. Conditions (31) can then be solved for a pair of optimal input taxes $\left(\hat{t}_1, \hat{t}_2\right)$. Once these tax rates are imposed in both countries, the users of the international

[6]The corner solution with only one firm i using the total *Pareto*–optimal input $v_i = V^*$ is not explicitly examined.

common property will behave according to reaction curves $v_i(V_{-i}; \hat{t}_i)$. They now reach their *Cournot–Nash* equilibrium in the *Pareto*–optimal combination of inputs P.

Whether an efficient use of the commons can really be achieved by setting national input taxes depends on the governments' capabilities (a) to agree on $\left(v_1^P, v_2^P\right)$ which implies an international distribution of welfare, and (b) to commit to a corresponding pair of tax policies $\left(\hat{t}_1, \hat{t}_2\right)$. Even if the distributional issues can be settled, our policy analysis indicates that each government has an incentive to deviate from such an agreement. Consider figure 5 for a stylized situation where both the users of the commons and the governments behave as *Cournot* competitors in their games.

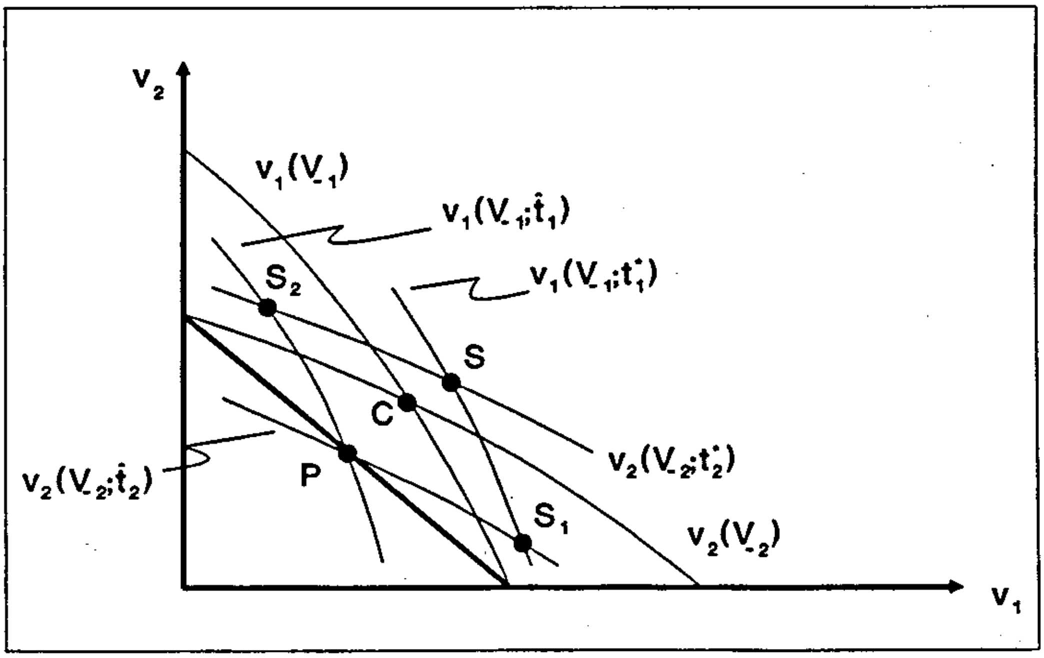

Figure 5: *Pareto*–inferior interaction of national policies

If government 1 were convinced that government 2 will indeed use $\hat{t}_2$, it would be optimal for 1 to impose a negative tax t_1^*, i.e. to pay a subsidy, which induces producer 1 to behave according to $v_1\left(V_{-1}; t_1^*\right)$. The equilibrium of the duopoly game can then be found in S_1, where an isowelfare contour of country 1 is tangent to the foreign duopolist's reaction curve $v_2\left(V_{-2}; \hat{t}_2\right)$.[7] In S_1 the common property is no longer efficiently used.

By the same token, S_2 is the equilibrium, if government 1 sticks to the agreement and government 2 deviates optimally by imposing a negative tax t_2^*. Finally, if both govern-

[7]To avoid cluttering the figure, isowelfare contours have not been drawn. Recall, however, that producer i's isoprofit contours for $t_i = 0$ can be interpreted as isowelfare contours of country i that are invariant to changes in t_i.

ments follow their incentives to cheat on each other, equilibrium S results. National welfare levels w, in figure 5 are ranked according to

$$w_1(S_1) > w_1(P) > w_1(S) > w_1(S_2), \tag{32}$$
$$w_2(S_2) > w_2(P) > w_2(S) > w_2(S_1), \tag{33}$$

where it is assumed that P was chosen such that it *Pareto*-dominates the non-intervention equilibrium C which in turn implies *Pareto* dominance over S.

Given this payoff structure, governments choosing optimal input taxes face a prisoners' dilemma, as do the duopolists in their game. Whether or not an efficient use of the international common property can be reached then depends on the governments' power to credibly commit themselves to (t_1^*, t_2^*). International treaties among governments might be considered as tools for these commitments. However, since policing such treaties in a world without a "world government" appears to be almost impossible, other ways to reduce utilization of international common property have to be found.

One way to think of would be unilateral policies by a single country. Such policies have recently been suggested in discussions about global environmental problems. They would call for a unilateral reduction in the use of the commons. The reasoning behind this proposal can vary: First, the idea of unilateral policy could be based on ethical as opposed to purely economic grounds, creating a willingness to ignore the costs of this policy. Second, the government which implements this policy could be willing to accept a welfare loss because it expects benefits in other areas, such as international reputation, foreign policy or future negotiations on other environmental problems. If the country under consideration is relatively large, it could assume the role of what political scientists call a "hegemon". In the context of international trade policy several authors pointed to the beneficial role of hegemonial powers such as Britain in the 19th century and the U.S.A, after the Second World war for establishing a liberal trade order (cf. *Kindleberger 1973, 1986, Keohane 1984)*. In the model of an international commons examined here, a hegemonial government *i* would unilaterally impose a tax on inputs v_i. From the comparative statics of the model we know that v_i decreases and v_j increases. While other countries get a free ride, however, there is a favorable net effect (25) on the commons. Political scientists sometimes point out that there can even be a gain to the hegemon from unilateral action, if the relative size of the hegemonial country exceeds a critical value (cf. *Snidal 1985)*.

4.2 Design of a Retaliatory Mechanism

If we do not trust in unilateral action and in the workability of international agreements, we could think about mechanism to enforce treaties among governments. Both the theory and the practice of international trade policy provide suggestions. Article XXIII of the GATT, for example, basically describes a retaliatory mechanism to enforce agreements among the member countries (cf. *Dam 1970, p. 79*). This can be used analogously for the problem of an international commons considered in this paper. Continuing interaction among the players is a necessary prerequisite for retaliation to work in a game with simultaneous decisions. Suppose that the policy decisions of governments 1 and 2 have to be made not only once, but for a finite or infinite number of times. This is most easily modelled in a framework of supergames or repeated games, assuming that our previous policy game, now called the constituent game, is played over and over again.

Imagine, at the beginning of their interaction governments 1 and 2 follow a two-step procedure. They first bargain over the distribution of the commons, given the restriction that only efficient uses are to be considered. The outcome of this bargaining implies a pair $\hat{t}_1, \hat{t}_2$ of optimal national input taxes. Secondly, they design a mechanism for retaliation in case one of them deviates from the tax rate implying *Pareto* optimality. Two different setups have to be distinguished for this second step: (1) Infinitely many repetitions of the constituent policy game. (2) Finitely many repetitions of the constituent policy game.

Consider the case of infinitely many repetitions first. The "folk" theorem from game theory suggests that governments can indeed guarantee that P in figure 5 is reached. Call choosing $\hat{t}_i$ in the constituent game a strategy of C(ooperation), and choosing t_i^* a strategy of N(on-cooperation) on part of government i. a_{it} is used to denote government i's action in round t of the repeated game. One mechanism among many others to ensure that both governments will not deviate from $\hat{t}_i$ is the following:

$$\begin{aligned} a_{i1} &= C \\ a_{it} &= \begin{cases} C & \text{if} \quad a_{j\tau} = C, \quad \tau = 1, \ldots, t-1, \quad j \neq i \\ N & \text{otherwise.} \end{cases} \end{aligned} \tag{34}$$

Each government starts out with C in round 1. If it ever observes that its opponent chose N, it will use N forever after. If both governments use a discount factor $\delta \in]0,1[$ to discount future welfare levels, it can easily be shown that a rational government 1 will never deviate as long as

$$\delta \geq \frac{w_1(N,C) - w_1(C,C)}{w_1(N,C) - w_1(N,N)} := d_1, \tag{35}$$

where $w_1(a_1, a_2)$ denotes country 1's welfare as a function of the actions of governments 1 and 2 (see, for example, *Dixit 1987*). If an equivalent condition holds for government 2, no deviation will occur, and an efficient use of the international common property prevails throughout. The intution behind this result is that a government weights the immediate benefit from deviating against the permanent loss from the resulting retaliation. If the future is not discounted too heavily, i.e., for values of *8* not too small, it will not be worthwhile deviating.

Other mechanisms can be designed, involving also less dramatic forms of retaliation (for a general discussion see *Fudenberg/Maskin 1986).* Recent work by *Van Damme (1989)* and *Farrell/Maskin (1989)* on "renegotiation-proof equilibria" suggests that there are even ways to punish a deviator such that the retaliating country does not get hurt. The overall message from these game-theoretic analyses is clear: If the governments face infinitely many rounds of policy interaction, there are mechanisms which generate an efficient use of the international common property as equilibrium of the supergame. Rational governments which care only about national welfare are induced to follow a course of tacit coordination despite the prisoners' dilemma structure of the constituent game. This result readily generalizes to other payoffs and to more than two governments (cf. *Fudenberg/Maskin 1986).*

In reality it can be doubted whether governments think of themselves as taking part in an interaction of infinite length. In particular, they could feel unsecure about the time they will remain in office. This, however, is easily modelled in the approach outlined so far, since a probability /x < 1 of staying in power for the next round conditional on being in power in the current round of the game simply implies a lower discount factor *8.* This, however, makes an efficient use of the commons more difficult to achieve.

If, on the other hand, both governments face an interaction of a known finite length *T,* game theory suggests that the Parefo-inferior outcome of the constituent game prevails in every round. In the last round, both governments will rationally choose *N.* Knowing this, the best they can do in the round before the last is to choose also *N.* Due to the logic of backward induction, the commons is not efficiently used. This result, however, is fairly counter-intuitive. In real-world situations, one would expect some connection between the rounds of the repeated game, allowing a government to build up a reputation which can be used later on.

Recent game theory provides a number of approaches to reconcile formal analysis with our intuition (cf. *Van Damme 1987, p. 166).* In models with (a) bounded rationality, (b) incomplete information, or (c) satisfying behavior cooperative behavior for all but a limited number of rounds arises. As for (a), we can think of situations where governments have only imperfect recall of the history of the game. Most relevant for (b) is the build-up of reputation in a sequential equilibrium (cf. *Kreps et al. 1982)* where a government does not know its opponent's payoffs with certainty. Since it revises its subjective probability distribution of the different types from the behavior it observes in the game, the government with an informational advantage can use its behavior to build up a reputation and use it afterwards. As an example for (c), so-called ε-equilibria can be considered. Under this setup, a government will only deviate from the contract, if this promises a discounted welfare gain of more than ε.

The approaches mentioned show that even with an interaction of finite length rational governments can reach cooperative behavior and an efficient use of the international common property at least temporarily. The imperfections needed in the models to generate these results are nicely connected to economic interpretations relevant for real-world situations. The optimistic conclusion from the case with infinitely many repetition therefore carries over to an interaction of given length.

There is, however, one fundamental drawback to retaliatory mechanisms. Since the international common property under consideration will often be considered environmentally valuable, retaliation which hurts the environment by increasing the utilization of the commons will appear unacceptable to many people. Government might then look for other instruments to be used for retaliation. Trade policy measures are a prime candidate which can already be found in a number of international environmental agreements. This, however, raises new issues, such as the question of whether a trade policy based mechanism to protect international common property is compatible with the GATT (see e.g. *Economist 1992, pp. 10-17*).

4.3 International Ownership of Firms

As pointed out in section 2, cross ownership among the user firms can mitigate or even solve the problem of the commons without government intervention. The main reason for this result was that an oligopolistic user of international common property accounts for some or all of his external effects on other users, if he holds a partial equity interest in these rival firms. In reality, however, there will often be international ownership of firms which does not qualify as cross ownership among firms in the sense used above. Instead, ownership will be more dispersed and it will not alter an oligopolist's profit maximization problem as assumed before. We can then adopt an idea first formulated in a paper by *Macho-Stadler/Verdier (1991)* in the context of a strategic design of managerial incentives. Imagine citizens of country j holding a stake e_{ji} in a firm in country i. Given an input tax rate t_i, this firm still maximizes its full profit $f(v_i, V_{-i}) - (p + t_i)v_i$, i.e. international ownership does not affect input decisions and the allocative inefficiency on the commons. What does change, though, is government i's policy decision. Its welfare function is now given by

$$w_i = \left(1 - \sum_{j \neq i} e_{ji}\right)(f(v_i, V_{-i}) - (p + t_i)v_i) + t_i v_i + \sum_{j \neq i} e_{ij}\,(f(v_j, V_{-j}) - (p + t_j)v_j) \quad (36)$$

Government i accounts both for foreign shares e_{ji} in its national firm and for its own citizens' shares e_{ij} in foreign firms. Maximization yields the following conditions for non-cooperatively chosen national tax rates $\tilde{t}_i$:

$$\tilde{t}_i = -f_{V_{-i}} \frac{dV_{-i}}{dv_i} + \underbrace{\sum_{j \neq i} e_{ji} f_{V_{-i}} \frac{dV_{-i}}{dv_i}}_{(i)} - \underbrace{\sum_{j \neq i} e_{ij} f_{V_{-j}} \frac{dV_{-j}}{dv_i}}_{(ii)} - \underbrace{\sum_{j \neq i} e_{ji} \frac{v_i}{dv_i/dt_i}}_{(iii)}, \qquad i = 1, \ldots, n. \tag{37}$$

The first term is equivalent to the solution (29) to the non–cooperative policy problem without international ownership of firms. If all $e_{ij} = e_{ji} = 0$, $\tilde{t}_i$ in (37) reduces to t_i^* derived earlier. The following terms (i)–(iii), however, are all unambiguously positive.[8] Therefore, we get higher input tax rates under international ownership compared to the case without international ownership:

$$\tilde{t}_i > t_i^* \tag{38}$$

The three effects working towards higher input taxes are quite intuitive:

(i) Country i carries only part of the reduction in firm i's profits caused by the shifting of market shares after a rise in t_i (indirect effect).

(ii) Country i receives some of the increased profits of firms $j \neq i$ caused by the shifting of market shares after a rise in t_i (indirect effect).

(iii) Countries $j \neq i$ carry part of the tax increase in country i through their shares in firm i (direct effect).

Implicit differentiation of (37) shows that both an increase of e_{ij} and an increase of e_{ji} unambiguously increase the optimal tax rate t_i. Further inspection of (37) shows that tax rates will be positive for high values of $\sum_{j \neq i} e_{ji}$ and/or high e_{ij}'s.

International ownership of the oligopolistic users therefore reduces the inefficiency on an international commons by inducing governments to pay lower subsidies or even impose taxes in their non–cooperative policy game. In analogy to the case of partial equity interests among the oligopolists one might ask whether there exist international ownership structures such that the policy game among governments yields tax rates which in turn cause the oligopolistic users to choose input levels such that *Pareto* efficiency on the commons is achieved.

[8] Note that dV_{-j}/dv_i in (iii) is positive, since an increase in t_i causes a decrease in v_i, an increase in v_j, and a decrease in V, therefore a decrease in V_{-j}, too.

To fix ideas, consider the special case of only $n = 2$ firms and governments. From (31) we know expressions for optimal tax rates $\hat{t}_i$ from the first order conditions of joint welfare maximization. Substituting these tax rates into (37) one can solve the system for e_{12} and e_{21}. Since the equations are not yet fully solved, i.e. e_{12} and e_{21} still depend on v_1 and v_2, no general conclusion can be drawn. For the symmetric case of $v_1 = v_2$, however, the expressions for e_{12} and e_{21} both take the value of 1/2. This should be interpreted as follows: If the two governments agree on sharing the commons equally ($v_1 = v_2$), it is sufficient for their non-cooperative policy to yield the taxes leading to *Pareto*-efficient use of the common property, if each country owns half of the other country's firm.

These results are compatible with the conclusions drawn from partial equity interests in section 2. For public policy, however, there is an important difference: Partial equity interests among the users of international common property can be considered a *Coasian* solution to the problem of the commons. It's the users themselves internalizing their externalities. If the private sector does not generate this solution, governments have to step in. Since they face a collective dilemma situation similar to the oligopolists', they have to find ways to commit themselves to the use of optimal taxes. International ownership of the firms helps because it gives each government an interest in the foreign countries' firms. Governments can even create a substitute for such international ownership in case it does not exist to a desirable extent. They can provide each other with claims against one's own firm's profit. Such an "exchange of hostages" alters national welfare calculations in a way favorable to an efficient use of the international common property.

5 Conclusion

The previous sections pointed to the fact that for a common property outside the jurisdiction of a single government, the well-known problem of the commons tends to be aggrevated by the policy decisions of rational welfare-maximizing governments. In addition to the inefficiency arising from the private decisions of the users, there is an incentive for the governments hosting the user firms to implement policies which further increase the overexploitation of the commons.

While governments could set national tax rates such that the firms are induced to use the common property efficiently, they will prefer to take policy measures that work in exactly the opposite direction. Using an argument familiar from the rent-shifting models in the international economics literature, it was shown that governments will want to subsidize their national firms.

Since agreements among governments to implement the policies that achieve efficiency are inherently unstable, other solutions to the twofold problem of the commons were discussed.

Repeated policy decisions in a framework of infinitely or finitely many repetitions of the constituent policy game are likely to generate cooperative behavior and an efficient use of the commons. International ownership of the user firms induces governments to account for the effects of their own policies on other nations. If the market itself does not create the *Coasian* solution of partial equity interests among the user firms, governments can use or even simulate international ownership as a way to change their welfare functions, which in turn leads to policies which increase efficiency on the commons.

Clearly enough, a number of issues relevant to common property remained excluded. For example, there was no entry of new users. Such entry, however, can be a further important source of overutilization. In the analysis of the exploitation of international common property presented in this paper, the output price was taken as given. Therefore, changes in the consumer surplus were not considered. This was done to isolate the issue of using the commons efficiently. From the literature on rent–shifting in international oligopolies the effects of such changes on the choice of optimal policies are well–known and can easily be applied to our model. Furthermore, this literature indicates that there would be an additional effect of a non–constant output price on the optimal policy, if more than one user firm is located in a country. Under such circumstances a government has to balance the rent–shifting effect of its policy against the price decreases resulting from an input subsidy. Policy will be used to generate more collusion among the domestic firms. The optimal subsidy then tends to be lower than in the case examined in the paper. For a large number of domestic firms government will increase efficiency on the commons since an input tax will be optimal in this case.

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