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Tropical Deforestation: Markets and Market Failures

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This paper puts forth a joint project model to examine tropical deforestation. Activities to curb deforestation yield private goods, local (country-specific) public goods, and global public goods. Local public goods are private among countries, but public within the country. Markets can operate with respect to the private goods, while nations are motivated to strike bargains with one another with respect to the country-specific public goods. Suboptimality stems from the global public goods and the positive externalities that preservation activities of one country confer on another. This suboptimality can be attenuated if the developed countries establish property rights to genetic material from the rainforests. Much can be done to promote allocative efficiency and these actions should be accomplished prior to the institution of the supranational linkage. Since the bulk of the global public benefits are derived by the developed countries, they are in a weak bargaining position with respect to the shrinking rainforests. An early agreement is in their interests even if the bargain favors the tropical countries.

TROPICAL DEFORESTATION: MARKETS AND MARKET FAILURES

Executive Summary

At least four different activities result in tropical deforestation. Annually, wood production contributes to about 32 percent of deforestation (45,000 sq. km.); cattle ranching to about 11 percent (15,000 sq. km.); and the provision of infrastructure to another 8 percent (12,000 sq. km.). By far the major damage is attributed to "shifted cultivators," who clear the forests in hopes of sustaining a living. These forest farmers account for just under 50 percent of deforestation annually, or some 70,000 sq. km. Some experts attribute a much greater amount of destruction to these farmers. Since much of the nutrient stock is in the biomass of the tropical forest itself, clearing the forest typically leaves the soil infertile. After one or two harvests, soil nutrients are depleted and the forest farmer must clear additional forest tracts.

The underlying causes of these activities are rooted in misdirected government policies, population pressures, and collective action problems. In most tropical countries, the forests are public lands managed by government officials who have allocated few if any resources to protect the forests from exploitation. For example, these officials often grant short-run concessions to logging companies in return for a fraction of the wood's value. Given the short-term nature of the contract, frequently involving only a few years, these companies have no incentives to manage the forest resource in a renewable fashion. Another misdirected policy involves the institution of land tenure policies requiring the forest lands to be improved by the would-be owners in order to gain title. "Improvements" often result in the forest being cleared, thus leading to a nonsustainable agricultural activity. These misdirected policies can be corrected if governments in the tropics begin to understand the losses that they impose on their own people and if, moreover, developed countries pay for the benefits that they derive from the existence of the forests. These payments may provide additional incentives for governments with tropical forests to allocate resources to preserving the forests.

This paper puts forth a joint product model to examine tropical deforestation. Activities to curb deforestation yield private goods (e.g.,

timber, nontimber products), local (country-specific) public goods, and global public goods. Local public goods are private among countries, but public within the country. Within the host nation, tropical forests provide local public goods in terms of watersheds, erosion control, localized climate effects, and nutrient recycling. Developed countries also gain local public goods including ecosystem linkages and genetic materials gathered from the rainforests. Global public goods include the storage of carbon and biodiversity.

Markets can operate with respect to private goods derived from the rainforests, while nations are motivated to strike bargains with one another with respect to the country-specific public goods. Market failures stem from the global public goods and the positive externalities that preservation activities of one country confer on another. This market failure can be attenuated if the developed countries recognize the establishment of property rights to the genetic material gathered from the rainforest. If, for example, tropical nations were to receive some royalties from the use of genetic materials taken from their forests, even when this material is subsequently synthesized, then tropical countries would better account for developed countries' public benefits, and would be more willing to preserve their forests. If properly motivated, the governments in tropical countries will rethink misdirected policies and may institute some population controls.

The paper underscores the relative bargaining disadvantage of the developed countries, since these countries have more to lose in potential benefits as rainforests shrink by 2 percent a year. A more flexible stance on behalf of the developed countries is recommended based upon recent advances in the theory of bargaining. The sooner the developed countries realize their bargaining disadvantage regarding preserving the tropical forests, the quicker a negotiated outcome will be concluded. An earlier agreement giving the developed countries a smaller share of a large prize is better than holding out for a larger share of a smaller prize or no prize at all.

A potential source of inefficiency stems from free riding <u>within</u> the set of developed countries. In many ways, the greatest source of inefficiency may come from the developed countries when they attempt to shift burdens for forest preservation among themselves.

TROPICAL DEFORESTATION: MARKETS AND MARKET FAILURES*

1. INTRODUCTION

The rate of tropical deforestation has accelerated in the last decade. In 1979, approximately 75,000 square kilometers (sq. km.) of tropical forests were being destroyed annually by a variety of activities; in 1989, approximately 142,000 sq. km. were being destroyed annually (Myers, 1992a, 1992b, 1991). This latter figure corresponds to approximately 1.8 percent of the remaining 8 million sq. km. of tropical forests.[1] If current rates of exploitation continue, and evidence suggests an acceleration of deforestation (Repetto, 1988; Myers, 1992a, 1992b), then tropical forests may virtually disappear in just over 50 years. Since tropical forests contain over half of the world's species of plants and animals, the clearing of these forests would have a significant impact on the earth's biodiversity. The biodiversity of the tropics has provided people with important benefits; for example, one-quarter of all prescription drugs sold in the United States are derived from tropical plants (Repetto, 1988). If these forests are destroyed, the discovery of additional drugs from tropical plants will not be possible. Tropical biodiversity also provides genetic material useful in genetic engineering for creating, for instance, more pest-resistant crops. In addition, tropical plants and animals involve crucial interrelationships with species worldwide; the loss of tropical biodiversity may adversely affect ecological balances elsewhere. These forests also influence climate patterns both locally and globally, and their destruction could have devastating consequences on food production (Myers, 1992a, ch. 15). In short, tropical forests provide a host of local benefits (e.g., watersheds, soil erosion protection, timber and nontimber products) and global benefits (e.g., biodiversity, carbon storage).

If tropical forests are so valuable, then why does the world now confront large scale destruction and degradation of this unique ecosystem? The answer involves a complex collective action problem that includes participants at the supranational, national, and local levels. As for most collective action problems,[2] the agents' (e.g., national governments, timber concessions, forest farmers) pursuit of their self-interest with respect to the exploitation of tropical forests creates an outcome in which almost everyone may be impoverished. This collective action problem raises a host of questions: Can market arrangements between tropical nations and developed nations operate so as to allocate resources from the tropical forests in an efficient manner? Are supranational structures needed, and, if so, how should they be designed? What is the likely outcome of negotiations between tropical countries and concerned nations in the developed world? In particular, who is at a bargaining disadvantage and who can be expected to underwrite the sought-after preservation? What are the sources of inefficiency with respect to tropical deforestation?

The primary purpose of this article is to provide some answers to these questions. More specifically, this paper identifies the collective action problems associated with tropical deforestation and, more important, recommends policy strategies on behalf of developed countries for promoting more efficient use of tropical forests. In particular, we argue that the private outputs and the country-specific public outputs, derived from the rainforests, provide an opportunity for markets to operate and for bargains to be struck so as to allocate resources more efficiently than is usually presupposed. Residual sources of inefficiency stem from global public goods and positive externalities conferred on nations by preservation activities. For global public benefits, the bulk of these benefits is experienced by the

developed countries that have the knowledge and technology necessary for biotechnology. The asymmetric impact of global warming also directs more of the carbon sequestering benefits, derived from tropical forests, to the developed countries, located in the higher latitudes. More optimal preservation activities would follow if developed countries recognized the tropical nations' property rights to genetic materials gathered from their forests. Furthermore, the developed countries must account better for the asymmetry of benefits. If market-promoting activities were pursued, then tropical nations would have a greater stake in their forests and would allocate more resources to protect these forests from population pressures. In addition, tropical nations would be more motivated to avoid misdirected policies. Developed countries must realize that they are bargaining over a shrinking forest. An earlier agreement giving the developed countries a smaller share of the gain may be better than a later agreement with a larger share. The specificity of the local public benefits supports negotiations being conducted at the supranational level.

The remainder of the paper contains five sections. Section 2 presents an overview of the tropical deforestation problem, and classifies benefits derived from tropical forests in terms of the degree of publicness. Section 3 presents a joint product model depicting the likely allocative behavior of national governments with respect to tropical forests in the absence of a supranational agreement. Section 4 depicts some simple game representations of the deforestation problem and analyzes the nature of possible bargains that may be struck at the supranational level. Additional aspects concerning bargains and linkages at the supranational level are examined in section 5. Concluding remarks follow in section 6.

2. ON TROPICAL FORESTS

An overview of the problem

The use of remote sensors has increased researchers' abilities to measure the extent and depletion of tropical forests; but measurement is still far from perfect. Although a similar picture of tropical deforestation emerges regardless of the source consulted,[3] the exact extent of deforestation reported varies by source. In Table 1, average annual tropical deforestation in the 1980s is indicated in hectares (1 hectare = 2.5 acres) for selected countries, using calculations from the World Resources Institute (1990). The middle column lists the (average) annual reduction of the country's tropical forest, while the right-hand column translates these losses into a percent of the country's remaining forests. In a recent contribution, Norman Myers (1991, p.6) puts the annual percentage losses for some countries at a much greater rate: Ivory Coast at 15.6 percent, Nigeria at 14.3 percent, Thailand at 8.4 percent, Madagascar at 8.3 percent, and the Philippines at 5.4 percent. At current rates of exploitation, tropical forests may disappear altogether in some of these countries within a decade.

A number of important facts can be drawn from Table 1. First, the greatest forest losses involve Brazil, India, Indonesia, and Colombia. Any agreement between the developed countries and these four tropical nations to curb deforestation would have a significant impact on the problem. Second, Brazil is by far the greatest source of tropical deforestation. Third, deforestation plagues much of the tropics including Southeast Asia, Asia, Central America, South America, and Africa. Fourth, similar percentage losses can imply vastly different losses in hectares (e.g., compare Brazil and Vietnam).

At least four different activities result in tropical deforestation.[4]

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Table 1
Tropical Deforestation in the 1980s:
Some Selected Countries

Country	Average Annual Deforestation, 1980s: Extent of Deforestation in hectares	Average Annual Deforestation, 1980s: Percent of Nation's Forest
Brazil	9,050,000	1.8
Colombia	890,000	1.7
Costa Rica	124,000	6.9
Ecuador	340,000	2.3
India	1,500,000	2.3
Indonesia	920,000	0.8
Ivory Coast	510,000	5.2
Madagascar	156,000	1.2
Malaysia	255,000	1.2
Mexico	615,000	1.3
Myanmar	677,000	2.1
Nigeria	400,000	2.7
Philippines	143,000	1.5
Thailand	397,000[a]	2.5
Vietnam	173,000	1.7
Zaire	370,000	0.2

Source: World Resources Institute (1990, Table 19.1, pp. 292-93).

[a] 1978 - 1985 annual deforestation.

Annually, wood production contributes to about 32 percent of deforestation (45,000 sq. km.); cattle ranching, exclusively in South America, to about 11 percent (15,000 sq. km.); and the provision of infrastructure to another 8 percent (12,000 sq. km.). By far the major damage is now attributed to "shifted cultivators," who clear the forests in hopes of sustaining a living. These forest farmers account for just under 50 percent of deforestation annually, or some 70,000 sq. km. Some experts, such as Myers (1992b), attribute a much greater amount of destruction to these farmers. Since much of the nutrient stock is in the biomass of the tropical forest itself, clearing the forest typically leaves the soil infertile. After one or two harvests, soil nutrients are depleted and the forest farmer must clear additional forest tracts. Unlike the temperate forest where organic matter builds up in the soil, tropical forests must depend on rapid recycling as high temperatures and heavy rainfall quickly break down soil nutrients.[5] In consequence, agricultural endeavors, such as farming or cattle ranching, are often not sustainable once the forests are slashed and burned.

The underlying causes of these activities are rooted in misdirected government policies,[6] population pressures, and collective action problems. In most tropical countries, the forests are public lands managed by government officials who have allocated few if any resources to protect the forests from wanton exploitation. These officials often grant short-run concessions to logging companies in return for a fraction of the wood's value. A prime example is Indonesia (Gillis, 1988; Repetto, 1988). Given the short-term nature of the contract, frequently involving only a few years, these companies have no incentives to manage the forest resource in a renewable fashion by planting trees for future harvests (Hyde and Newman, 1991). Another misdirected policy involves the institution of land tenure policies requiring

the forest lands to be improved by the would-be owners in order to gain title. "Improvement" often results in the forest being cleared, thus leading to a nonsustainable agricultural activity, owing to the infertility of the soil. Yet another misdirected policy is the subsidization of alternative agricultural uses that are unprofitable without significant government outlays. Browder (1988) documents the case of government subsidies to cattle ranchers in Brazil. Negative returns to cattle ranching in the absence of subsidies indicate that resources need to be channeled elsewhere.[7] These misdirected policies can be corrected if governments begin to understand the losses that they impose on their own people and if, moreover, developed countries pay for the benefits that they derive from the existence of the forests. These payments may provide additional incentives for governments with tropical forests to allocate resources to preserving the forests.

Population pressures pose the greatest threat to tropical forests. During the 1990s, population is predicted to expand by one billion people with 60 percent of this expansion in the tropical countries (Myers, 1992a, p. xviii; 1992b, p.12). Many decades must pass before these nations will achieve zero population growth. If nothing is done to stem these population pressures, tropical forests will vanish. Peasants are forced to exploit the forests because of unequal landholdings that leave most arable lands controlled by relatively few families. The solutions are not easy. Perhaps the best solution would be education, followed by population control. People must be provided with a means to support themselves without having to resort to the exploitation of the forests. A land reform policy to redistribute arable lands among the landless peasants would also alleviate the problem, but vested interests will surely oppose such reforms. Once again, a government must anticipate sufficient gains from, say, payments from developed countries

to institute such reforms as a means for protecting tropical forests.

Finally, collective action problems characterize the manner in which the shifted cultivators treat the tropical forest as an open-access commons.[8] In particular, each cultivator considers his/her immediate needs without concern for the damage that his/her activities impose upon others in current and future generations. When a cleared forest tract becomes infertile, the forest farmer moves on and destroys additional forest cover. Since the cultivator does not plan to pass the tract on to his/her heirs, he/she does not account for future ramifications. Unless the government limits access to the forests, and this may require a large scale allocation of resources to protect its property rights to the forests, the shifting cultivator will continue to eliminate tropical forests.

Local and global benefits derived from tropical forests

The notion of a public good is relevant for the characterization of the benefits derived from tropical forests. A good is a pure public good when its benefits are nonrival and nonexcludable; it is a private good when its benefits are rival and excludable. The benefits of a good are nonrival whenever a unit of the good can be consumed by one agent without detracting, in the slightest, from the consumption opportunities still available to others from the same unit. The biodiversity contained in a tropical forest provides nonrival benefits to the host country's population as well as to people worldwide, since preservation of the associated gene pool enriches everyone. If, however, an agent's consumption of a unit of a good fully eliminates any benefits that others can obtain from that unit, rivalry in consumption exists. Timber is rival, because two consumers cannot use the same log.

A second distinguishing characteristic of goods is excludability of

benefits. Goods whose benefits can be withheld costlessly by the owner or provider display excludable benefits. Benefits that are automatically available to all agents once the good is provided are termed nonexcludable. If biodiversity is maintained, then everyone derives benefits; biodiversity is nonexcludable. Because biodiversity is both nonrival and nonexcludable, it is a pure public good. In contrast, timber yields excludable benefits, inasmuch as the provider can withhold the timber unless a payment is received. Timber is both excludable and rival and, hence, is a private good.

In the case of public goods, the size of the group that derives nonrival and nonexcludable benefits determines the extent of publicness. If a good's benefits are nonrival and nonexcludable on a global scale, as in the case of biodiversity, then the good is a global public good. If, in contrast, a good's benefits are nonrival and nonexcludable only within a country's boundaries, or within a region, then the good is a local public good.

Private goods can be parceled out and sold in markets. Economic agents can only receive the benefits of a private good if they pay for them, since benefits can be withheld. On the other hand, nonpayers cannot be denied the benefits from a public good since, once the good is provided, the benefits are received by payers and nonpayers alike within the group for which the benefits extend. In the case of public goods, those agents who value the public good most will provide it, while others will rely or free ride on the provision efforts of others. Markets fail with public goods, since free riding leads to a suboptimal amount of resources being allocated to provision.

Now we return to the benefits of tropical forests. The preservation of tropical forests provides multiple outputs; hence, joint products are present (see, e.g., Cornes and Sandler, 1984). Furthermore, these outputs are private, locally public, and globally public. Outputs from the tropical

forest that are private among and within nations include timber and nontimber products (e.g., fruits, nuts). Within the host nation, tropical forests provide local public goods in terms of watersheds, erosion control, localized climate effects, and nutrient recycling. These benefits, while nonrival and nonexcludable to nearby residents, do not typically extend beyond a nation's boundaries.[9]

Developed countries also gain local public benefits from the preservation of tropical forests. These benefits derive from a unidirectional externality that flows from the tropical nation to the developed nation. Examples include ecosystem linkages between the tropics and the temperate zones. A fascinating instance, mentioned by Myers (1992a, pp. 59-60), serves to illustrate the concept. Myers notes that songbirds protect crops in the U.S. by feeding on insect pests. Many of these songbirds migrate to Central and South America for the winter months. If the songbirds' winter habitats are reduced through tropical deforestation, then their numbers will dwindle. In consequence, insect pests may experience a population explosion, thereby causing widespread crop damage. Based on the songbirds' migration patterns, the public benefits are localized in the temperate zone in terms of pest control.

Another localized public benefit conferred on developed nations by tropical forests, concerns the sequestering of carbon in the trees. Though much uncertainty still exists regarding the quantitative relationship between atmospheric warming and the accumulation of carbon in the atmosphere (Houghton and Woodwell, 1989; Nordhaus, 1991), scientists agree that the atmospheric buildup of greenhouse gases, such as carbon dioxide, will heat the atmosphere. If tropical forests are burned, carbon is released into the atmosphere. In recent years, as much as one-third of the annual increase in atmospheric

carbon is attributed to tropical deforestation (World Resources Institute, 1990, Table 24.2; Myers and Goreau, 1991, p.217). A unidirectional externality arises because global warming is expected to have its greatest impact on the higher latitudes. Even though some climatic change may occur in the tropics, most of the impact of global warming is expected to take place in the temperate and arctic zones; hence, the benefits derived from the storage of carbon by tropical forests are mostly experienced by the developed nations. The ability of tropical forests to curb global warming is a valuable asset. In fact, massive reforestation programs involving one million sq. km. or 100 million hectares of tree plantations in the tropics have been suggested as a short-run means of offsetting carbon accumulation (Myers and Goreau, 1991).

A third local public benefit for the developed countries involves the option value provided by the gene pools stored in the tropical forests. Option value relates to the uncertain benefits that might arise from a future use of the forest myriad species--for example, the discovery of a cure for a disease from a tropical plant. Insofar as some developed countries have the knowledge and technology to exploit these gene pools, while the tropical countries do not, the resulting benefits from this exploitation are apt to be concentrated in the developed countries.

A last class of benefits, derived from the tropical forests, are global public goods. An example is the existence value associated with the biodiversity contained in the tropical forests. A second example is the bequest value that the current generation worldwide derives from passing an asset on to a future generation.

3. JOINT PRODUCT MODEL

In the last section, tropical forests are depicted as yielding private

and public joint products.[10] To show the implications of these varied joint products, I present a formal representation. For the sake of simplicity, only two economic agents are assumed: (1) a coalicion of developed countries, and (2) a coalition of tropical countries. The model can be easily modified to allow developed and tropical nations to act independently. The preservation of a unit of the tropical forest, denoted by q, is assumed to produce four outputs: a coalition-specific private good, a global public good, and coalition-specific public goods for <u>each</u> of the two coalitions.[11]

The strictly increasing, quasi-concave utility function of the developed-countries coalition--coalition 1--is

$$U^1 = U^1(y^1, s^1, X^1, Z), \tag{1}$$

where y^1 is a private numéraire good unrelated to tropical forest, s^1 is a coalition-specific private good (e.g., ecotourism), X^1 is a coalition-specific public good, and Z is a global public good. The joint product relationships, described below, allow us to express utility in terms of the numéraire and the activities of preserving tropical forests, activities q^1 and q^2, that are undertaken in coalition 1 and coalition 2 (i.e., the tropical-countries coalition), respectively.

In Figure 1, the joint product relationships for each coalition is depicted. For coalition 1, a unit of q^1 yields output x^{21}, x^{11}, z^1, and s^1. The first superscript on the x's indicates the coalition-specific public good produced, while the second superscript denotes which coalition's preservation activity is responsible for providing this public good. Hence, x^{21} indicates the amount of coalition 2's local public good provided by coalition 1's provision of q^1. The superscripts on the production coefficients, α^{ij}, are interpreted analogously.

According to Figure 1, one unit of q^1 yields $\gamma^1 q^1$ units of s^1; $\alpha^{11} q^1$

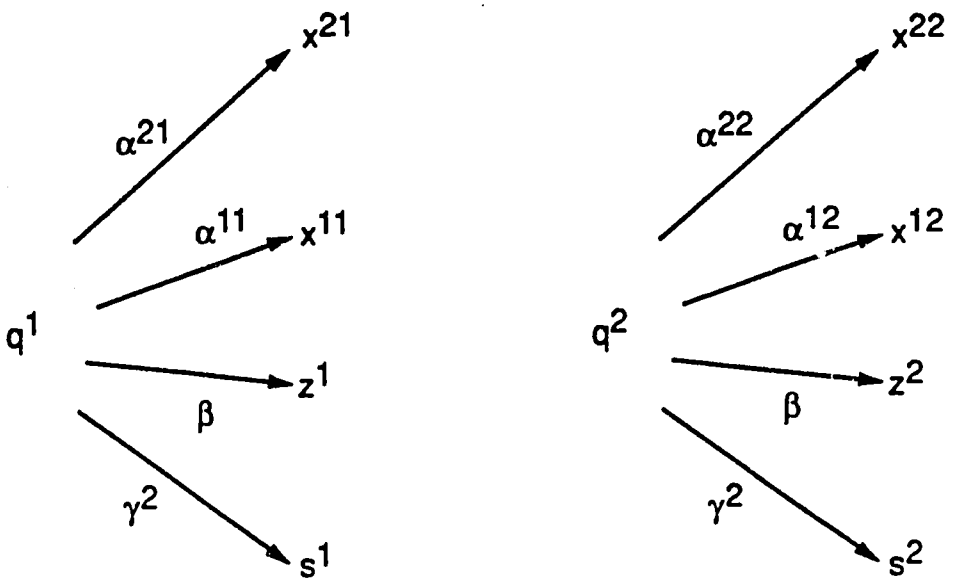

Figure 1: Joint Product Relationship

units of x^{11}; $\alpha^{21}q^1$ units of x^{21}; and βq^1 units of z^1. All of this detail is necessary to account for the direction of the externalities and for the degree of publicness. The following joint product relationships follow from Figure 1 and relate joint products to the q's:

$$s^1 = \gamma^1 q^1, \tag{2}$$

$$X^1 = x^{11} + x^{12} = \alpha^{11}q^1 + \alpha^{12}q^2, \tag{3}$$

and

$$Z = z^1 + z^2 = \beta(q^1 + q^2). \tag{4}$$

In (3), X^1 denotes the total amount of coalition 1's local public good derived from its own support of forest preservation and that of coalition 2. In (4), the total quantity of the global public good, Z, is also related to tropical forest preservation activities of both coalitions. This same relationship holds for coalition 2, because output Z is purely public for the two coalitions If the 1 superscripts are replaced by 2's and vice versa in (2)-(3), the joint product relationships for coalition 2 follow, regarding s^2, X^2 and Z. Each coalition must allocate resources to preserving tropical forests and to the numéraire good. The latter indicates all nonpreservation activities. The linear budget constraint for coalition 1 is

$$I^1 = y^1 + pq^1, \tag{5}$$

in which I is the coalition's income, p is the per-unit price of tropical forest preservation, and unity is the per-unit price of the numéraire. If the joint product relationships are substituted into the utility function, then coalition 1 faces the following allocation problem,

$$\max_{q^1}\{U^1[y^1, \gamma^1 q^1, \alpha^{11}q^1 + \alpha^{12}q^2, \beta(q^1 + q^2)] \mid I^1 = y^1 + pq^1\}, \tag{6}$$

when it acts independently of coalition 2.

This independent behavior is known as Nash behavior and corresponds to a

coalition maximizing its utility, while treating q^2 as fixed at the other coalition's best response level for q^2. The first-order conditions associated with (6) can be simplified to

$$\gamma^1 MRS^1_{sy} + \alpha^{11} MRS^1_{X^1y} + \beta MRS^1_{Zy} = p, \tag{7}$$

where MRS^1 denotes coalition 1's marginal rate of substitution (MRS) between the jointly produced output and the numéraire indicated by the subscripts. For instance, we have

$$MRS^1_{X^1y} = (\partial U^1/\partial X^1)/(\partial U^1/\partial y^1);$$

analogous expressions hold for the other MRS expressions. In a similar fashion, coalition 2 would satisfy the following first-order condition:

$$\gamma^2 MRS^2_{sy} + \alpha^{22} MRS^2_{X^2y} + \beta MRS^2_{Zy} = p. \tag{8}$$

A Nash equilibrium corresponds to the vector of preservation efforts, (q^1_N, q^2_N), that simultaneously satisfies (7) and (8).

We focus our remarks on coalition 1's Nash condition in (7), since equation (8) for coalition 2 is interpreted in an identical fashion. The left-hand side of (7) indicates the marginal benefit that coalition 1 receives from supporting or underwriting a unit of tropical forest preservation, whereas p is the marginal cost associated with preservation. Marginal benefits consist of the weighted sum of the MRSs derived from three outputs: the coalition-specific private good, the coalition-specific public good, and the global public good. The presence of the former two outputs motivates the developed-countries coalition to support preservation activities beyond what it receives in terms of the global public good. Thus, coalition-specific outputs, public or private, help motivate the developed countries to assist in the preservation of tropical forests. The greater the number and/or amount of these coalition-specific outputs, the greater will be the support provided by

the developed countries. Hence, the presence of unidirectional externalities arising from such things as ecosystem linkages or carbon storage should induce the developed countries as a whole to participate in preserving tropical forests. But will this support be adequate or optimal? And what additional caveats are needed?

To answer the first question, we present the first-order conditions for the Pareto optimal provision[12] of q^1:

$$\gamma^1 MRS^1_{sy} + \sum_{i=1}^{2} \alpha^{i1} MRS^i_{Xiy} + \sum_{i=1}^{2} \beta MRS^i_{Zy} = p. \tag{9}$$

By comparing (7) to (9), we see that efficiency does not result from independent behavior, since coalition 1 <u>does not account for coalition 2's local public benefit</u> ($\alpha^{21} MRS^2_{X2y}$) <u>and global public benefits</u> (βMRS^2_{Zy}), derived from coalition 1's provision of q^1. Nash equilibrium implies suboptimal preservation activities even though the presence of coalition-specific outputs make coalition 1 provide more preservation support than in the absence of these outputs. Similarly, coalition 2's preservation activities are suboptimal, because it fails to account for coalition 1's local and global public benefits when deciding provision levels of q.

The recognition of coalition-specific benefits, nevertheless, provides a greater motivation on behalf of the developed countries to back up their interests in the tropical forests with support in terms of resources. As the constituencies of the developed countries become more informed about the positive benefits that tropical forests provide for them, there will be increased pressure on elected officials to do something. Increased efficiency would result from independent adjustment if property rights to these global and coalition-specific benefits (e.g., biodiversity, the gene pools of the tropical forest) were recognized and enforced. If, for example, tropical nations were to receive royalties from the use of genetic material taken from

their forests, even when this material is subsequently synthesized, then tropical countries would better account for coalition 1's public benefits,[13] and would be more willing to preserve their forests. Given the location of these forests and the direction from which benefits flow, developed countries are in a weak bargaining position and should be more accommodating to the nations hosting the rainforests. Tropical nations will be more willing to listen to the wishes of the developed nations if suggested actions are made worthwhile. With adequate payments, the tropical nations would have resources and motivation to do something to protect their property rights to the forests. This includes curbing the unchecked expansion of forest farmers and reducing the subsidization of uneconomical activities in the forests.

Tropical nations are also motivated by their private benefits and local public benefits (e.g., control of soil erosion, watersheds) to preserve some forests. The importance of these local public benefits may be better understood in the wake of forest floods and other dire consequences blamed on forest clearing. The greater is the proportion of private and local public outputs, the larger is the potential role of markets among nations for allocating resources in an efficient manner. The institution of property rights, as suggested above, is a necessary ingredient for the operation of markets. The presence of global public benefits means, however, that suboptimality and market failures are still a factor.

An important caveat applies, since we have studied everything at the supranational level as though there are two coalitions of nations. Additional sources of suboptimal behavior may stem from free riding and market failures within the coalition; for example, some developed countries may try to rely on the U.S. to support tropical forest preservation so as to foster the flow of public benefits to all developed countries. In many ways, the greatest source

of suboptimality may come from the developed countries when they attempt to shift burdens for forest preservation among themselves. The coalition-level analysis is informative, since it indicates that there are some incentives to bargain and exchange between the developed world and the tropical nations. A second caveat concerns the actions of the coalition leaders, who have been assumed to work in the interests of their constituencies. This, too, may be violated when leaders pursue their own interests and/or agenda. These public choice considerations are relevant to any situation where governments are the actors.

4. SOME SIMPLE GAME REPRESENTATIONS

To highlight the possibility of bargaining between the two coalitions for the purposes of alleviating the market failure associated with tropical forests' global public outputs, we present some simple game representations. The actual numbers used to illustrate the game payoffs are not as important as the pattern of payoffs and the underlying equilibria implied by the payoffs. In section 3, the level of preservation supported is a continuous choice variable; in this section, it is a discrete variable. Each coalition has two strategies: support or finance a 25 percent curtailment in deforestation as compared to some baseline level of deforestation (e.g., reducing annual deforestation by 35,500 sq. km.), or do not support a reduction.

In Figure 2, four representative payoff matrices that might result are displayed. Four possible strategy combinations are possible: (1) both coalitions support curbing deforestation (i.e., exploitation cut by 71,000 sq. km. annually), (2) only coalition 1 supports the reduction in deforestation, (3) only coalition 2 supports the reduction of deforestation, and (4) neither coalition supports curbing deforestation. For each of the four game scenarios

depicted, the rows indicate the two strategies of coalition 1, and the columns denote those of coalition 2. The first number in each cell is the payoff or net gain of coalition 1, while the second number is the payoff or net gain of coalition 2.

Market failures involving global public goods are often characterized as a Prisoner's Dilemma game in which each player (or coalition) adopts a dominant strategy[14] to not contribute (Sandler, 1992a). An example is illustrated in the top left-hand matrix of Figure 2. The payoffs are based on the following scenario: Curbing forest exploitation by 25 percent in tropical nations involves a cost of 7 to the participating coalition, but confers a benefit of 5 to each of the two coalitions. The "spillover" of benefits is indicative of the nonrivalry and nonexcludability of the global public benefits. If both coalitions support the reduction in deforestation, then each receives a net benefit of 3 (see cell a) as coalition-specific costs of 7 are deducted from a coalition's gain of 10. Gross gains for each coalition are 10, because each coalition's action confers benefits of 5 to both coalition. When a single coalition brings about the reduced deforestation, this coalition gets a net gain of −2 (= 5 − 7), while the inactive coalition derives a gain of 5 from the other coalition's unilateral action (see cells b and c). If neither curbs deforestation, net gains are zero all around in cell d.

From either coalition's viewpoint, not curbing deforestation is a dominant strategy in the Prisoners' Dilemma matrix, because no matter what coalition 2 (1) does, coalition 1's (2's) payoffs (5 and 0) are greater than the corresponding payoffs from reducing deforestation (3 and −2) in our hypothetical scenario. Each coalition therefore uses its dominant strategy and ends up in the cell marked with an asterisk in the top left-hand matrix:

Ma

		Coalition 2	
		S	D
Coalition 1	S	a 3, 3	b −2, 5
	D	c 5, −2	d * 0, 0

Prisoner's Dilemma

		Coalition 2	
		S	D
Coalition 1	S	a 3, 3	b * −2, 3
	D	c * 5, −2	d −4, −4

Chicken: Symmetric

		Coalition 2	
		S	D
Coalition 1	S	a 5, 1	b * −1, 4
	D	c * 6, −3	d −4, −4

Chicken: Asymmetric

		Coalition 2	
		S	D
Coalition 1	S	a 5, −1	b * −1, 3
	D	c * 6, −4	d −4, −4

Chicken: Asymmetric

S = Support [preservation by reducing forest exploitation by 25 percent of a baseline standard.

D = Don't support preservation

* Indicates Nash equilibrium

Figure 2: Sample Games

hence, deforestation rates continue unabated. Both coalitions would be better off if they could agree to co-sponsor reduced deforestation, so that each gains 3. These potential gains can motivate bargaining among the participants. Cell d is a Nash equilibrium as it represents the best response for each coalition to its counterpart's best response of not curbing deforestation.

For tropical deforestation, the Prisoners' Dilemma is unlikely to be the appropriate game structure, since if neither coalition tries to bring about a reduction in deforestation, they will lose valuable local and global public goods. Status quo exploitation is not without costly repercussions. A more realistic scenario corresponds to the top right-hand game matrix, which is an example of the Chicken game.[15] The payoff pairs for cells a, b, and c are computed as before, but the payoff in the absence of any preservation activity in cell d is a loss of, say, 4 to each coalition. With this matrix, there is no strategy that dominates; however, there are two Nash equilibria marked with asterisks when pure strategies are used.[16] At these equilibria, neither coalition would unilaterally change its strategic choice if given the opportunity, since such a change would result in a payoff loss of 2 as payoffs either change from 5 to 3 or from −2 to −4. Once games other than Prisoners' Dilemma are acknowledged, equilibria may involve one or more players acting in a manner to protect the forests. Unless the equilibria involves full cooperation--cell a--potential gains can be achieved through bargaining as shown below.

In the bottom two matrices, an asymmetry is built into the representative games, so that both coalitions do not face identical outcomes. Asymmetry also fosters realism, since the two coalitions may experience different benefits from reduced deforestation owing to different coalition-

specific local public goods. For the bottom left-hand matrix, a reduction in deforestation still costs 7 to the supporter, but yields 6 in benefits for coalition 1 and only 4 for coalition 2. No action creates losses of 4 for each coalition.[17] Once again, there is no dominant strategy and the Nash equilibria are the off-diagonal cells b and c.

In the bottom right-hand matrix, the asymmetry is enhanced so that a 25 percent reduction in deforestation gives 6 in benefits to coalition 1 but only 3 in benefits to coalition 2. Although there are still two Nash equilibria along the off-diagonal cells, cell b is more apt to be the equilibrium. This follows because the do-nothing strategy dominates the reducing deforestation strategy for coalition 2--i.e., the payoffs of 3 and −4 are larger or equal to the corresponding payoffs from doing something. If coalition 1 reasons that coalition 2 will adopt its dominant strategy, then coalition 1 will be better off supporting the reduction in deforestation on its own. The more asymmetric are the payoffs between the coalitions, the more likely that the coalition with the most to lose from deforestation will step in and do something. Given the significant local and global public outputs that the technologically advanced countries derive from tropical forests, asymmetry is surely present and this weakens the developed countries' ability to bargain.

The bargaining set for the top right-hand matrix is depicted in Figure 3. The horizontal axis depicts coalition 1's payoffs, while the vertical axis denotes coalition 2's payoffs. In the absence of a bargained agreement the participants will be at payoffs (−2, 5), (5, −2), or (1/2, 1/2). The first two points are the Nash equilibria with pure strategies, while the latter point is the Nash equilibrium with mixed strategies (see footnote 16). The fully cooperative outcome is (3,3) when bargaining is costless. If the coalitions were to try to coordinate between cells b and c, then the line

19A

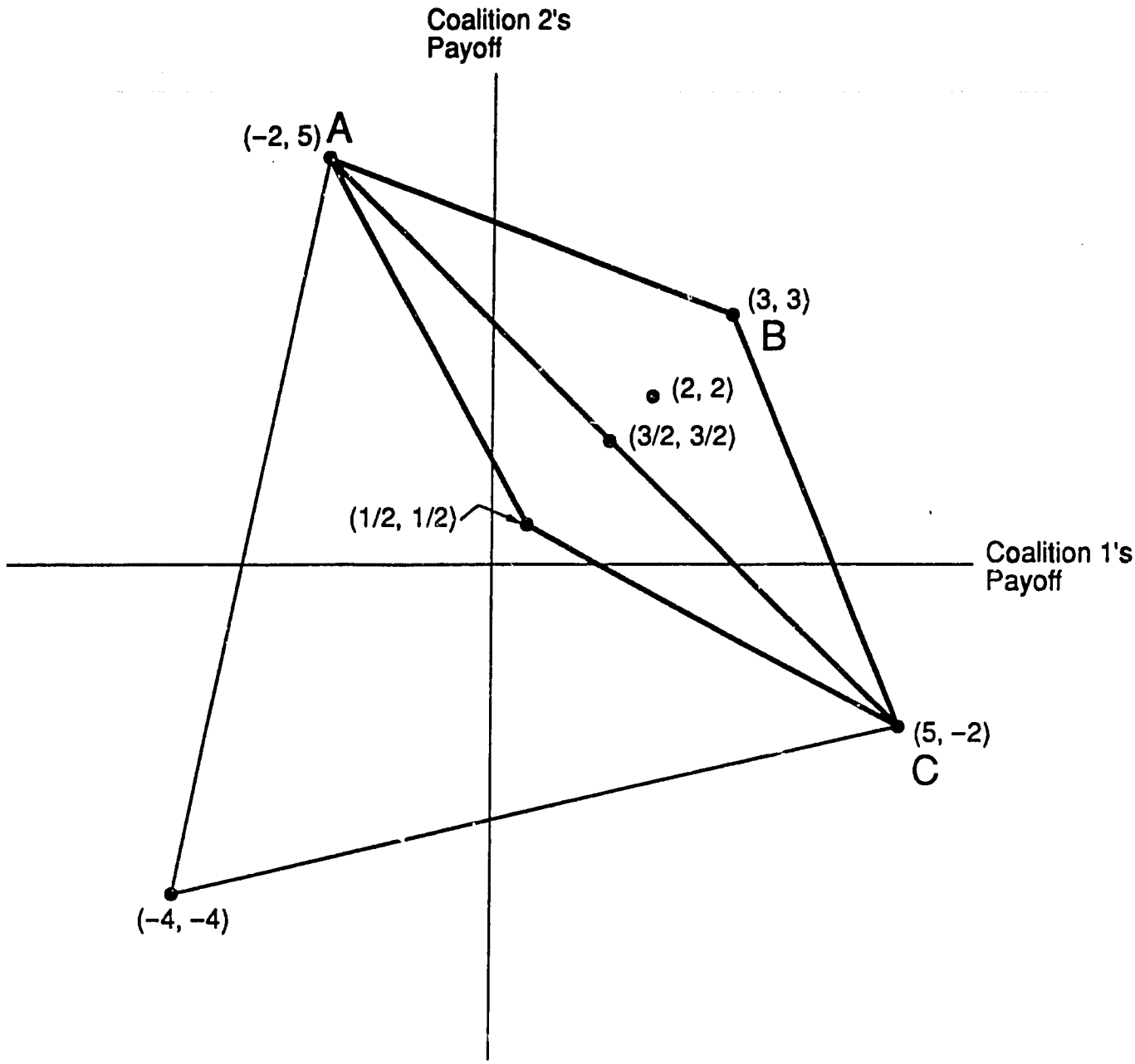

Figure 3: Chicken Bargaining Set

segment joining (−2, 5) and (5, −2) would indicate the possible payoffs. For example, an agreement to alternate 50 percent of the time between these Nash equilibria would yield the payoff of 3/2 on average to the two coalitions. The bargaining set would then correspond to the triangle ABC and its interior points, such as (2, 2).

A drawback of the standard analysis of cooperative games concerns the assumption of costless transactions. In the real world, participants to an agreement must expend resources to reach <u>and</u> <u>enforce</u> a bargained outcome. These resources are transaction costs and serve to limit the true size of the bargaining set. Transaction costs are especially germane to supranational linkages. The Earth Summit in Rio during June 1992 involved large transaction costs and resulted in a weak agreement with no enforcement mechanism. In fact, a key potential participant--the United States--refused to sign the biodiversity treaty, which sought to protect the tropical nations' property rights to genetic material gathered from its forests. Protection of these rights in some form is, as shown above, crucial to fostering more efficient outcomes, because it motivates the tropical nations to account for some of the local public outputs that their forests give to the developed nations.

5. BARGAINING: FURTHER CONSIDERATIONS

<u>Bargaining over a shrinking forest</u>

There are a number of aspects of the tropical forest scenario that are not captured by the standard, static analysis of bargaining. A crucial consideration concerns the shrinking nature of these forests. If current deforestation trends continue, then remaining forests will contract by at least 2 percent per year as the tropical and developed nations jockey for position. Ariel Rubinstein (1982) formulated a bargaining model in which two

players negotiate over a shrinking cake;[18] the analogy is particularly appropriate for tropical forests.

If the objective of the negotiations is shrinking with time, then an early agreement will yield a greater sum of payoffs to the participants than a later agreement. The final outcome is a generalized Nash bargaining solution (Binmore, 1991, p.207)[19] where the product

$$(u_1 - d_1)^{\delta_1}(u_2 - d_2)^{\delta_2} , \tag{10}$$

is maximized. In (10), the u's denote the net payoff to the respective coalition from an agreement, and the d's denote the disagreement payoff if no agreement is reached. The exponents, δ_1 and δ_2, indicate the bargaining powers of the respective coalition. A small value of δ_1 relative to δ_2 implies that coalition 2 has more bargaining strength and, ceteris paribus, will fare better from the negotiated outcome. These bargaining strengths are related to the coalition's discount rate, since $\delta_i = 1/\rho_i$, where ρ_i is the ith coalition's discount rate (Binmore, 1991). If a coalition's discount rate is large, then it wants immediate gains (i.e., future gains are discounted greatly); this impatience puts the coalition at a bargaining disadvantage.

The coalition of the developed countries is apt to be the most impatient, since it has the wherewithal now to exploit the genetic material of the tropical forests. Additionally, the derived benefits from the storage of carbon in the tropical forests are greater in the developed countries, which are located in the higher latitudes. Since the demand for environmental preservation tends to have a high income elasticity, the constituencies in the developed countries can be expected to apply pressures on leaders to do something quickly to stem the clearing of the tropical forests. The Rubinstein model suggests that the final bargain achieved with respect to

preserving the rainforests will favor the tropical countries. The sooner the developed nations realize their bargaining disadvantage, the sooner a negotiated outcome will be concluded. An earlier agreement giving the developed countries a smaller share of a larger prize is better than holding out for a larger share of a smaller prize, or no prize at all!

Supranational linkage

Supranational linkages or structures have existed throughout history. Perhaps the most common instance is the military alliance. NATO, for example, has linked nations in North America and Europe to a common defense pact since 1949. Other supranational structures include the United Nations, the International Monetary Fund, the European Space Agency, and the European Economic Community. To determine whether a supranational structure is justified for managing the tropical forests, one must first determine the allocative efficiency in the absence of a structure. The noncooperative Nash equilibrium is the likely outcome without a supranational linkage. Before expending resources to support a supranational linkage, policy makers should first contemplate policy reforms that can improve the noncooperative outcome. Thus, changes in property rights to tropical genetic material that foster efficiency without the need for a formal linkage need to be instituted first.

Once policies are instituted to make the noncooperative outcome as efficient as possible, a supranational linkage can be considered. Two questions then arise: (1) Is a linkage needed? and (2) If needed, what form should the linkage take? The first question requires at least two calculations. First, a supranational structure must be shown to yield positive net linkage benefits to the group. That is, efficiency gains achieved through a supranational linkage must outweigh the costs of the

linkage. Efficiency gains from linkage must be beyond those associated with the best noncooperative outcome. If this noncooperative outcome yields near-efficient results after policy reforms are instituted, then a supranational linkage is unlikely to be warranted, since linkage benefits are modest and may be overwhelmed by transaction costs. The bargaining set is consequently small. Second, a linkage is not warranted unless it gives net gains to each potential participant.

When a supranational structure passes the sufficiency requirements, its form must be decided. Linkage form requires a determination of common funding requirements, the voting rule, decision bindingness, the meeting frequency, and the enforcement mechanism (Cauley, Sandler, and Cornes, 1986; Sandler, Cauley, and Cornes, 1983). "Loose" structures maintain the autonomy of the participants; hence, meetings are infrequent, votes must be unanimous, decisions are not binding, and there is no enforcement mechanism. Most supranational structures are loose. Tighter structures foster cooperation, thereby augmenting linkage benefits and costs. Loose structures are justified if linkage costs increase faster than linkage benefits as structures are tightened. If tropical countries place great importance on their autonomy, as all do, linkage costs are expected to increase far faster than linkage benefits, and a loose structure will result.

Unfortunately, loose supranational structures are unlikely to achieve much in the way of forest preservation. Hence, supranational linkage, including United Nations conventions, as suggested by Myers (1992b), while well-intentioned, do not hold much promise for preservation. The best hope is to give tropical nations a reason for accounting for the benefits that their forests confer on the world community. Property rights reform at the supranational level and a willingness on behalf of the developed nations to

negotiate can achieve much.

6. CONCLUDING REMARKS

Tropical deforestation is a complex problem stemming from a host of activities including forest farming, logging, cattle ranching, and large-scale infrastructure projects. The driving forces behind these activities are population pressures, highly skewed land ownership, and/or misdirected government policies. Since tropical forests yield private outputs and local public outputs, markets and quasi-markets can function, to some extent, to promote allocative efficiency. In the case of local public goods, such as erosion control and watersheds, tropical countries have a vested interest to do more to protect the forests that they manage. Positive externalities conferred on developed countries, in terms of gene pools and carbon storage, should provide an impetus for these nations to assist in the preservation of tropical forests. This impetus can be strengthened greatly if developed countries recognize the tropical countries' property rights to genetic materials gathered from their forests by giving them a share in the earnings from medicinal and other discoveries. Without these property rights, tropical nations will be less concerned about the public goods that their biodiverse forests provide to the developed world. If properly motivated, the governments in tropical countries will rethink misdirected policies, such as subsidizing uneconomic activities and myopic land tenure policies. With sufficiently high stakes, these countries will expend more resources to protect forests from encroachment. Some curbs on population growth might also be instituted.

The paper has underscored the relative bargaining disadvantage of the developed countries. It is in these countries' interests to reach an

agreement over the tropical forest soon. Each passing year means the destruction of thousands of square kilometers of primary forests and the unique species that they house. A more flexible stance on behalf of the developed countries is recommended based upon recent advances in the theory of bargaining.

The institution of supranational linkages should not be considered until policies to foster markets are enacted. In all likelihood, these structures will be loose, since efficiency gains may not be very large once policies to support markets are more fully pursued.

FOOTNOTES

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1. The literature on tropic deforestation is quite extensive. A few representative articles include Browder (1988), Deacon (1992), Ehui, Hertel, and Preckel (1990), Englin and Khan (1990), Gillis (1988a, 1988b), Gillis and Repetto (1988), Hyde and Newman (1991), Myers (1991, 1992a, 1992b), Panayotou (1992), Pearce (1991), Pearce and Myers (1990), Repetto (1988,1990), and Sedjo (1992a).

2. On collective action problems, see Olson (1965), Hardin (1982), and Sandler (1992a).

3. See, e.g., Hyde and Newman (1991), Myers (1991, 1992a, 1992b), Pearce (1991), and Sedjo (1992a).

4. The numbers reported come from recent estimates provided in Myers (1992b, pp. 17-19) for 1989, where total deforestation is estimated at 142,000 sq. km.

5. Leaf litter decomposes in a mere six weeks in a tropical forest, in contrast to one year in a deciduous forest in the temperate zone (Myers, 1992a, p.34).

6. For an excellent treatment of these misdirected policies, see Repetto and Gillis (1988).

7. Myers (1992b) indicates that Brazil has stopped subsidizing new ranches, but Brazil still subsidizes established ranches. Some drop in the

clearing of forests for cattle ranching has resulted in recent years--a drop from 20,000 sq. km. to 15,000 sq. km.

8. On problems of the commons, see Cornes and Sandler (1983, 1986), Runge (1986, 1990), and Sandler (1992a, 1992b).

9. A partial exception is erosion control, since a benefit is conferred on nations downstream if a waterway is shared by more than one country.

10. Though a formal joint product model of tropical forests has not been presented in the literature, the existence of these joint products has been recognized by Hyde and Newman (1991), Pearce (1991), and Sedjo (1992a).

11. With the use of vectors, multiple outputs for each of these four types of outputs could be allowed.

12. This condition follows from maximizing $U^1(\cdot)$ subject to the constancy of $U^2(\cdot)$ and subject to an aggregate budget constraint:

$$I^1 + I^2 = y^1 + y^2 + p(q^1 + q^2).$$

A similar expression to (9) holds for q^2, provided that the 1's are changed to 2's.

13. This same point was raised by Sedjo (1992b).

14. A dominant strategy gives an agent a greater payoff regardless of the other player's action or strategy.

15. See Binmore (1991) for a discussion of some basic games, such as Chicken and Prisoners' Dilemma.

16. Another Nash equilibrium involves mixed strategies, in which a coalition randomizes its pure strategy, so that it is indifferent between the two strategies, given that the other coalition randomizes its strategy. For the top right-hand matrix of Figure 2, the mixed strategy equilibrium requires each coalition to play each strategy 50 percent of the time.

17. Asymmetric losses would have no effect, provided that each

coalition loses at least 3.

18. A particularly lucid presentation of Rubinstein's model can be found in Binmore (1991, pp. 203-12).

19. The Nash bargaining solution should not be confused with a Nash equilibrium. The former is a cooperative game notion, while the latter is a noncooperative game notion.

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