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ABSTRACT

Recent literature has explored both physical and policy linkage between trade and environment. Here we explore linkage through leverage in bargaining, whereby developed countries can use trade policy threats to achieve improved developing country environmental management, while developing countries can use environmental concessions to achieve trade disciplines in developed countries. We use a global numerical simulation model to compute bargaining outcomes from linked trade and environment negotiations, comparing developed-developing country bargaining only on trade policy with joint bargaining on both trade and domestic environmental policies. Results indicate joint gains from expanding the trade bargaining set to include environment, opposite to the current developing country reluctance to negotiate in the World Trade Organization on this issue. However, compared to bargaining with cash side payments, linking trade and environment through negotiation on policy instruments provides significantly inferior developing country outcomes. Thus, a trade and environment policy-linked negotiation may be better than an environment-only negotiation, but negotiating compensation to developing countries for environmental restraint would be better. We provide sensitivity and further analysis of our results and indicate what other factors could qualify our main finding, including the erosion of the MFN principle involved with environmentally based trade actions.

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1 Introduction

Since the early 1990s trade and environment has been a high profile issue, with environmental groups arguing that restrictions are needed on certain types of trade (species, tropical lumber, pollution intensive manufactures) to safeguard the environment, and developing countries opposing what they see as a new threat of trade restrictions against their exports. Where countries fail to institute policies which internalize global or cross-border environmental externalities, environmental groups argue that appropriate trade restrictions can improve resource allocation. Trade liberalization advocates, on the other hand, see trade measures as very much second-best environmental policy, and worry over environmental legitimization of new trade restrictions by protectionist interests.

In this paper we discuss possible developing country participation in possible future linked trade and environment negotiations in the World Trade Organization (WTO), which we suggest would largely break down on North-South lines. The South we see as the custodian of yet to be used environmental assets (forests) and the North as having a high existence value on these assets due to higher income.

Whether or not environmental justifications for the use of trade restricting policies should be part of any future (post Uruguay Round) trade negotiations is now a central issue. Developed countries, responding to pressures from their own environmental non-government organizations, have supported their inclusion, while developing countries have appeared more reluctant to engage in a linked negotiation; they instead seek direct compensation for implementing growth slowing environment protecting policies.

Here, we argue that global (and also cross-border) environmental externalities provide developing countries with strategic leverage over the use of trade restrictions by developed countries against their own exports. Although GATT-WTO tariff barriers in OECD countries are now low, sectoral barriers in textiles, apparel, footwear, steel and other areas are still significant, as are voluntary export restraints, regulatory restrictions in services, and the use of anti-dumping and countervailing-duty measures. Linking environmental and trade negotiations thus gives developing countries opportunities to restrain adverse trade policy in developed countries, with environmental concessions being available to bargain for lower trade barriers to their exports. Linkage expands the bargaining set, offering more opportunity to exchange concessions, which can result in more trade and lowered barriers. Seemingly, linked trade and environment negotiations should be embraced by both the developing and developed world as expanding the choice set for bargaining, leaving the question remaining as to why developing countries are opposed.

To explore these issues, we use a two-region (North-South) numerical simulation model of world trade and environment benchmarked to 1990 data and projected over a 100-year time horizon. We compute non-cooperative Nash equilibria (disagreement outcomes for bargaining), and bargaining outcomes (Nash bargaining) under both sole and joint bargaining involving trade and the environment. The trade side of the model is a conventional heterogeneous products (Armington) model, in which trade elasticities play a key role. The environmental structure of the model involves environmental assets in the South which are depleted more rapidly when used in trade-related production activities, and whose existence value enters North's preferences considerably more strongly than is the case for Southern preferences. The calibration of the model involves some strong assumptions and adjustments of data for model admissibility, but generates a specification with sharply asymmetric North-South endowments and preference weightings on environmental asset depletion.

The central case results we generate show that, relative to free trade, the South (as the smaller region) loses in a trade war. A trade-only negotiation helps both the North and South in lowering trade barriers, but a trade-only negotiation (with no side payments) leaves large barriers remaining in the North against the South. An environment-only negotiation is largely ineffective—because of the strongly asymmetric pattern of abatement costs and benefits—but a joint trade and environment negotiation allows the North to generate welfare gains from Southern environmental management and the South to lower Northern trade barriers. The theme is that developing countries should embrace a trade and environment negotiation as it provides them with more leverage over trade. However, in a negotiation with side payments the South does considerably better than in a constrained negotiation, suggesting that a trade policy-environmental policy negotiation may be an inferior negotiation; that is, a negotiation of cash compensation for environmental restraint is better for them.

In our concluding section, we also note that trade rule constrained bargaining in which existing trade rules (such as MFN) are taken to imply restrictions on the bargaining set may yield a different picture. If we consider trade and environment linkage as a proposal under which MFN trade rules would also be relaxed where environmental effects are at issue, and if an initial weakening of MFN could lead to further system-wide weakening in other areas, developing country concerns over a trade and environment negotiation may be more firmly based. In such cases, gains from expanded bargaining could be more than offset by losses from the weakening of prior agreed restraints on trade policy.

The paper is structured as follows. In Section 2 we outline our analysis and contrast it with that in earlier studies on linkages between trade and environment. Section 3 describes the structure of the model, while Section 4 describes the data and methodology used for calibration. Section 5 describes our experiments and presents our findings. Section 6 concludes.

2 Trade and Environment Linkage

The literature on linkage between international trade and environmental quality has primarily focused on two related questions: whether international trade contributes to lowered environmental quality (e.g. Anderson, 1992a; Anderson, 1992b; Dean, 1992; Rauscher, 1992); and whether trade liberalization is desirable, both in terms of global efficiency and individual-country interest, when environmental emissions are not internalized (e.g. Dean, 1992; Pearce, 1992). The policy debate on trade and environment has also often been interpreted as reflecting concerns over these forms of linkage.

In this literature there is a presumption that linkage between trade and environmental policies is weak and that trade policies are ineffective instruments of environmental protection—a conjecture confirmed by model-based estimates of trade-environment linkage (Perroni and Wigle, 1994). As Blackhurst and Subramanian (1992) have pointed out, there are also strategic reasons for linking trade and environmental policies in multilateral negotiations. This complementarity between trade and environmental policies, which stems from the asymmetric structure and distribution of the gains and losses across high and low income countries associated with each of these two policy dimensions, can also make global cooperation easier to sustain when pursued through linked negotiations.

The strategic linkage between trade policy and the environment discussed here does not seem to have been directly addressed in the literature. Barrett (1994) and Ulph (1996a, 1996b), among others, have studied the interaction between trade and environmental policies theoretically, but define the strategic element from the standpoint of the market structure in which firms operate. Copeland and Taylor (1995) have examined the interaction between trade, cross-border externalities and income levels in a general equilibrium model when countries differ in human capital and income (and when they are similar). They find that when countries differ in human capital and income levels, trade liberalization increases pollution and leaves the higher-income, capital-abundant countries worse off. They raise a possible link between North-South trade and environmental policies, but do not explore it in detail, and throughout their analysis trade policies are exogenous.

Papers that are related to the analysis we present here are Cesar and Zeeuw (1994), Spagnolo (1996), Ludema and Wooton (1994) and Nordhaus and Yang (1996). The first of these builds a general framework linking environmental cooperation with cooperation in some other, non-specified area. They show that cooperation in both areas is sustainable provided that the two games roughly offset each other. That is, agreements can be sustained if what a country gains from cooperating in one area is roughly equivalent to what the other one gains from cooperating in the other. Under this approach, the policy games are fully independent of each other, which is different from what would occur in a linked trade and environment policy negotiation. The Spagnolo paper analyzes strategic effects of linking international negotiations with different policies (which may include trade and environment) within a framework of repeated games. He finds that when issues are interdependent and are substitutes in governments' objective functions, linking agreements may help to sustain policy cooperation.

Ludema and Wooton use a partial equilibrium model to examine a noncooperative game between two countries in the presence of a cross-border externality. They show that countries would tend to use environmental policy as a substitute for trade policy and viceversa, and that there will generally be a tendency for the externality to be overcorrected. They do not explore the possibility of environmental policy cooperation, although they point out a linkage between trade and environment could be implicitly present in some free trade agreements involving countries of different size which contain some environmental provisions. This leads the larger country to give up its monopoly power to the smaller one as a form of side payment for agreeing to environmental cooperation. Strategic linkages between trade and environmental policies are not examined empirically.

Finally, Nordhaus and Yang use a multi-region dynamic general- equilibrium model to examine market, cooperative and noncooperative enviromental strategies.

They compute noncooperative Nash equilibria in environmental policies as well as cooperative equilibria where countries adopt globally efficient policies to reduce emissions. One of their findings is that the noncooperative strategy is superior to the (do-nothing) market strategy but inferior to cooperative policies. They also find that some high-income countries (such as the USA) may lose from cooperation relative to noncooperation, with the bulk of benefits from cooperation accruing to developing countries. In their model, bargaining solutions are not examined and no interaction between trade and environment is considered.

3 A Two-Region North-South Trade and Environment Model

We consider a world consisting of two regions, which we refer to as 'North' (N) and 'South' (S). Focusing on a two-region structure avoids the numerical complexities associated with computation of noncooperative equilibria in higher dimensions, and allows us to focus on two-player cooperative solution concepts. Computational limitations in working with noncooperative and cooperative game-theoretic solutions concepts rather than more traditional competitive equilibria thus severely restrict dimensionality in the numerical analysis.

We consider an environmental asset, E, which is entirely owned by the South, and can be viewed as a stock reflecting available tropical habitat. Each region produces two goods, a tradeable good X, a nontradeable good Y. Region S uses two factors in production, value added V, and the natural resource asset. Production in region N only uses value added. Each region views tradeables produced domestically and abroad as imperfect substitutes, and consumes both domestic and imported traded goods, along with own region nontradeables. The environment (available habitat) is depleted by its use in production, and enters the utility function of each region. Depletion occurs more heavily from use in production of the traded good. The endowment of value added is constant in each region, and equal respectively to G^N and G^S.

Production

The structure of production in the model is set out in Figure 1. CES functions are used, in which value added and the environmental asset can be transformed into an environment-using input at the lower level of nesting.[1] At the higher level of nesting, the environment-using input and value added are transformed into tradeable and nontradeable output. We use substitution elasticities of zero at the lower level, and of unity at the higher level. Value added used in the two levels of nest can be transformed at a constant marginal rate of transformation, which, for simplicity, we assume to be equal to unity.

The rationale for using this construction is that if a single level production structure were specified with the environmental asset and value added as the only inputs, to preclude partial internalization of the externality through input substitution a zero elasticity would be needed. However, with an unpriced input (the environmental asset) there would be infinite demand. The only mechanism for internalization in this

[1]Functional forms are described later in this section.

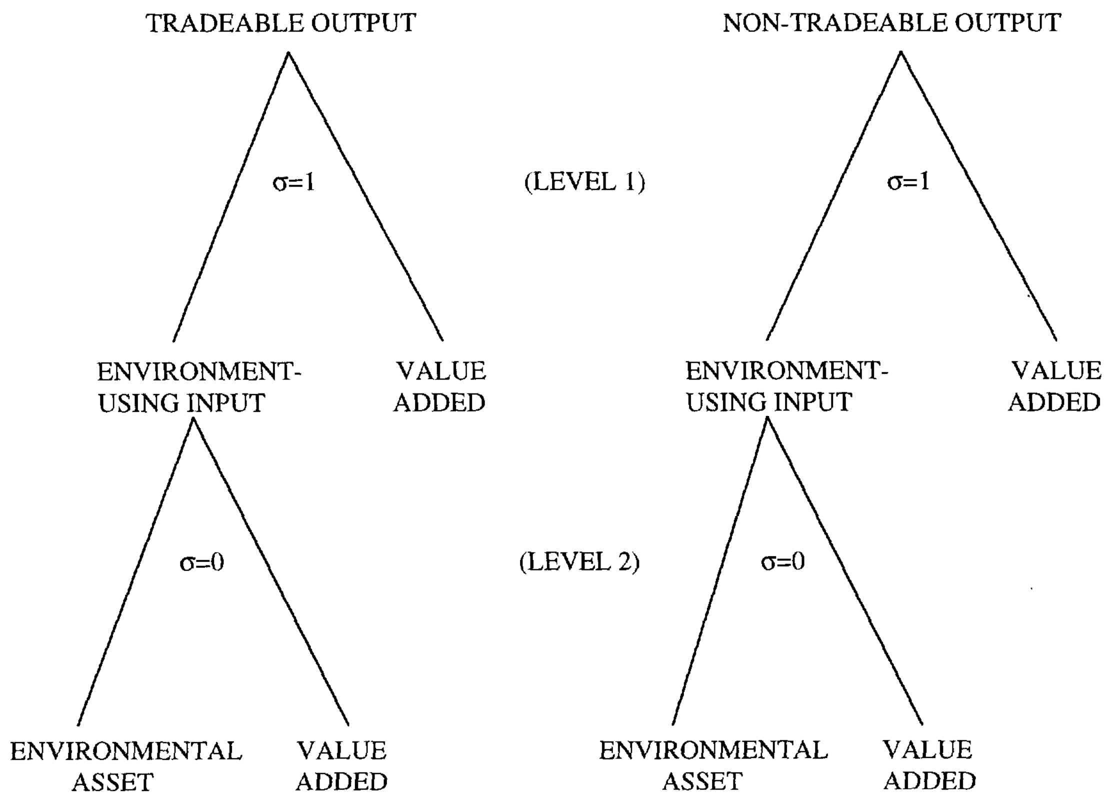

Figure 1: CES Production Structure in the Model (South Region)

case is through substitution between tradeables and non-tradeables via demand side effects. With two levels of production substitution, taxes on an environment-using input can be introduced, which will change the use of the environmental asset. The main difference between the tradeable and non-tradeable goods sectors lies in the share parameters on the environment-using input.

Environmental Taxes

Net-of-tax prices for value added and the environment-using input are denoted respectively as p^N and p^S and are the same within each region. Each unit of environment-using input employed in production in region S reduces global environmental quality by an amount ϵ. We consider taxes on the use of the environmental asset at rate τ^S, and hence the gross-of-tax prices of the environment-using input in the two regions are

$$p_E^N = p^N \tag{1}$$

$$p_E^S = p^S + \epsilon\tau^S. \tag{2}$$

Prices

Value added and the environment-using input are both used in the production of tradeables and nontradeables through unitary substitution elasticity, constant-returns-to-scale technologies. Thus, domestic prices of domestically produced goods are equal to unit costs:

$$p_X^N = c_X^N(p^N, p_E^N); \tag{3}$$

$$p_Y^N = c_Y^N(p^N, p_E^N); \tag{4}$$

$$p_X^S = c_X^S(p^S, p_E^S); \tag{5}$$

$$p_Y^S = c_Y^S(p^S, p_E^S). \tag{6}$$

For given output levels L_X^N, L_Y^N, L_X^S, L_Y^S, we can write aggregate domestic demands for the environment-using input (using Shephard's Lemma) as

$$D_E^N = L_X^N \frac{\partial c_X^N}{\partial p_E^N} + L_Y^N \frac{\partial c_Y^N}{\partial p_E^N}; \tag{7}$$

$$D_E^S = L_X^S \frac{\partial c_X^S}{\partial p_E^S} + L_Y^S \frac{\partial c_Y^S}{\partial p_E^S}. \tag{8}$$

Environmental Quality

Environmental quality enters the preferences of both the North and the South, but with a substantially higher share parameter in the North than in the South, reflecting the differential existence value placed on environmental assets by region. The quantity of environmental assets entering preferences as existence value equals the initial stock of assets less that amount used up in production (through deforestation, for instance). The period used for the model is a number of years or decades, during which significant depletion can occur depending upon the policy regime. For given demands for the environment-using input, environmental quality is then given as

$$Q = \bar{Q} - \epsilon(D_E^S), \tag{9}$$

where $\bar{Q}$ denotes the initial endowment of the environmental asset (before use in production).

Trade

Each region levies ad valorem import tariffs at rates t^N, t^S, where superscripts refer to the importing region (where tariffs are levied). The gross-of-tariff prices of imported tradeables in N and S are thus

$$q^N = (1 + t^N)p_X^N; \tag{10}$$

$$q^S = (1 + t^S)p_X^S; \tag{11}$$

Demands

Given preferences, a level of environmental quality Q, commodity prices p_X^N, p_X^S, p_Y^N, p_Y^S, q^N, q^S, and incomes I^N, I^S, utility maximization yields uncompensated demands for domestic goods, D_X^N, D_Y^N, D_X^S, D_Y^S, and uncompensated import demands, M^N, M^S. The marginal valuation for environmental quality in each country, v^N, v^S, is also a function of the same variables.

Expanded income in each region is written as the value of resource endowments, plus tariff revenue, plus revenues from environmental levies, plus the (shadow) value of environmental quality (note that the latter is a function of income itself, which makes the definition of I implicit)[2]:

$$I^N = p^N G^N + t^N p_X^S M^N + v^N Q; \tag{12}$$

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[2]This is added to income since environmental quality is purchased at its shadow price, but this price is not actually paid between countries, i.e. the North makes no actual payment to the South for the existence value of environmental quality they enjoy.

$$I^S = p^S G^S + t^S p_X^S M^S + \tau^S \epsilon D_E^S + v^S Q. \tag{13}$$

Market Equilibrium

Market clearing for competitive equilibrium in which use of the environmental asset is only charged through environmental levies requires the following:

$$L_X^N = D_X^N + M^S; \tag{14}$$

$$L_Y^N = D_Y^N; \tag{15}$$

$$L_X^S = D_X^S + M^N; \tag{16}$$

$$L_Y^S = D_Y^S; \tag{17}$$

$$D_E^N + L_X^N \frac{\partial c_X^N}{\partial p^N} + L_Y^N \frac{\partial c_Y^N}{\partial p^N} = G^N; \tag{18}$$

$$D_E^S + L_X^S \frac{\partial c_X^S}{\partial p^S} + L_Y^S \frac{\partial c_Y^S}{\partial p^S} = G^S. \tag{19}$$

Choice of Functional Form

In the numerical implementation of the model, unit cost functions for tradeables and nontradeables production are a Constant-Elasticity-of-Substitution (CES) aggregation of the environment-using input and value added prices:

$$c_X^N(p^N, p_E^N) \equiv \left[(1-\alpha_X^N)(p^N)^{1-\beta^N} + \alpha_X^N (p_E^N)^{1-\beta^N}\right]^{\frac{1}{1-\beta^N}}; \tag{20}$$

$$c_Y^N(p^N, p_E^N) \equiv \left[(1-\alpha_Y^N)(p^N)^{1-\beta^N} + \alpha_Y^N (p_E^N)^{1-\beta^N}\right]^{\frac{1}{1-\beta^N}}; \tag{21}$$

$$c_X^S(p^S, p_E^S) \equiv \left[(1-\alpha_X^S)(p^S)^{1-\beta^S} + \alpha_X^S(p_E^S)^{1-\beta^S}\right]^{\frac{1}{1-\beta^S}}; \tag{22}$$

$$c_Y^S(p^S, p_E^S) \equiv \left[(1-\alpha_Y^S)(p^S)^{1-\beta^S} + \alpha_Y^S(p_E^S)^{1-\beta^S}\right]^{\frac{1}{1-\beta^S}}. \tag{23}$$

where the βs are the elasticities of substitution between the environment-using input and value added, and the αs are share parameters.

Preferences for domestic goods and imports in each region are represented by a two-level nested Cobb-Douglas/CES aggregation of the form

$$H^N(D_Y^N, D_X^N, M_A^N, M_B^N) \equiv$$
$$(D_Y^N)^{\theta^N}\left[\delta^N(D_X^N)^{\frac{\sigma^N-1}{\sigma^N}} + (1-\delta^N)(M^N)^{\frac{\sigma^N-1}{\sigma^N}}\right]^{\frac{(1-\theta^N)\sigma^N}{\sigma^N-1}}. \tag{24}$$

$$H^S(D_Y^S, D_X^S, M_B^S, M_A^S) \equiv$$
$$(D_Y^S)^{\theta^S}\left[\delta^S(D_X^S)^{\frac{\sigma^S-1}{\sigma^S}} + (1-\delta^S)(M^S)^{\frac{\sigma^S-1}{\sigma^S}}\right]^{\frac{(1-\theta^S)\sigma^S}{\sigma^S-1}}. \tag{25}$$

where θ^N and θ^S are share parameters for nontradeables demand; δ^N and δ^S refer to the share of domestic goods in total tradeables demand; σ^N and σ^S are the elasticities of substitution between same-region tradeables and tradeables produced in the other region.

Preferences for consumption and environmental quality are represented by a Cobb-Douglas utility function:[3]

$$U^N(Q, H^N) \equiv Q^{\eta^N}(H^N)^{1-\eta^N}; \tag{26}$$

[3]For this specification, the marginal valuation for environmental quality is proportional to (non-expanded) income.

$$U^S(Q, H^S) \equiv Q^{\eta^S}(H^S)^{1-\eta^S}. \tag{27}$$

where the ηs are the Cobb-Douglas share parameters on environmental quality.

Policy Games in the Model

The model incorporates trade policy parameters in the form of tariffs, and environmental policy parameters in the form of environmental charges. A traditional tariff game can be analyzed (as in Johnson, 1953-4) in which regions play strategically against one another in tariffs. With the North being large and the South small, the presumption is that the North will gain from such a retaliatory game while the South will gain little, or more likely lose. There is also an environmental game that can be analyzed in terms of environmental charges associated with the use of the environmental asset. Since the South owns the environmental asset, and the North places a high existence value on the environmental asset, this gives the South a policy instrument to use jointly with trade policy in a linked trade and environment game which can lower Northern trade protection.[4]

In using the model, therefore, we go beyond conventional numerical simulation work which mainly focuses on Walrasian competitive equilibria, by computing nonco-

[4]Throughout our analysis we maintain the assumption that countries in each bloc are able to coordinate policies among themselves in an inter-bloc noncooperative equilibrium. Even though the necessary environmental institutional arrangements are not currently in place for such intra-bloc coordination to take place, they could well emerge in the future as has been the case in the trade area. In UNCTAD, for instance, the G77 emerged as the common developing country demand for special and differential treatment in GATT gained momentum in the 1970s (see Whalley, 1981).

operative equilibria and bargaining outcomes. To do this, we iterate over calculations of optimal policy responses by individual regions, subject to a full set of general equilibrium constraints (as set out above) until convergence to a Nash equilibrium is achieved. We are able to do this separately for tariff and environment policy games and for the linked trade and environment game. We also compute cooperative bargaining solutions associated with these games, adopting Nash's (1950) bargaining solution. This is the most widely used cooperative solution concept in the literature, although others, such as Kalai-Smorodinsky (1975), could alternatively be used. In computing bargaining solutions, we take the non-cooperative Nash equilibrium solution utilities as representing the disagreement point, simulate the utilities possibilities frontier under cooperation, and apply the Nash criterion to the product of the differences in region utilities along the frontier and disagreement utilities.

In our central case, with trade or trade and environment games, no side payments are considered, and thus the resulting outcomes remain second best allocations. Typically in such equilibria there will be less than full internalization of the environmental externality. We also compute bargaining with side payments. This realizes a full Pareto optimal allocation, and allows us to assess how far towards Pareto optimality a joint trade and environment policy-based negotiation could move.

Alternatively, we could view cooperation as a subgame perfect equilibrium of an infinitely repeated game, supported by the threat of future punishment in response to unilateral deviations from a coordinated strategy (trigger strategies). In this formulation we could explore whether a linked trade-environmental policy game makes cooperation in both areas easier to sustain in comparison with a scenario where the trade and environment dimensions of strategic interaction are examined in isolation from each other.

4 Data and Model Parameterization

We have calibrated the model set out above to a 1990 base case projected forward over a period of 100 years. The economies of the North and the South are both assumed to lie on a growth path on which value added, production and consumption grow at a constant rate, reflecting average growth rates over the period 1985-93. Data for this period implies rates of growth of 2.5% and 4% for the North and South respectively. We assume a discount rate of 5%.

The production and consumption (and hence trade) data we use are based on information taken from World Bank (1992), World Bank (1995), and IMF (1995). Non-environmental activities are disaggregated into two parts: traded and non-traded. The non-traded goods sector contains all distribution, transportation, construction, utilities, and government services. This corresponds roughly to 68% and 47% of GDP for the North and South respectively.

In representing the regions, we include countries for the South which account for a significant portion of key global environmental assets, such as tropical forest and biological diversity. These countries are listed in Table 1, and jointly control more than 80% of tropical forest and provide habitat for an unknown but presumed considerable proportion of species.[5] The North we take to be represented by OECD countries—

[5]As is well-known, tropical ecosystems have a higher and more diverse number of species in a

who jointly reflect the environmental concern over depletion of environmental assets and would be the lead players in any eventual trade and environment negotiation in the WTO—and the rest of the world.

Table 2 reports the base year 1990 data on production by region and the corresponding 1990-2090 discounted data. Table 3 gives share and elasticity parameters. In calibrating the model, we select a value of 2 for Armington substitution elasticities, a choice which is consistent with most model-based studies (e.g., Perroni and Wigle, 1994); we subsequently vary this value for sensitivity analysis.

Parameters for the environmental portion of the model, are obtained as follows. The environment-using input coefficients by region have been computed from input-output data for selected OECD countries.[6] We make the strong assumption that developing countries use the environment-using input in the two sectors in the same ratio as they are used in OECD countries. We consider the following sectors as providing environment-using inputs: agriculture, forestry and fishing, mining and quarrying; petroleum and coal products; electricity, gas and water; and construction.

We compute the amount of base-case environmental damage, in terms of depletion of the endowment of the South's environmental asset, as follows. The endowment of the environmental assets in the South, relative to which depletion occurs, is set to be

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given area than temperate ecosystems. It is estimated that between 40% and 90% of all species live in tropical region habitats (World Resources Institute, 1994).

[6]The countries are Germany, United Kingdom and United States. The input-output data has been taken from OECD (1995).

Table 1: Countries in the 'S' Region in the Model and Their Tropical Forest Cover

	Hectares 1990 (Thousands)	% of world tropical forests
Angola	24,074	1.37
Bolivia	49,317	2.81
Brazil	561,107	31.95
Cameroon	20,350	1.16
Central African Republic	30,562	1.74
Colombia	54,064	3.08
Congo	19,865	1.13
Gabon	18,235	1.04
Guyana	18,416	1.05
India	51,729	2.95
Indonesia	109,549	6.24
Malaysia	17,583	1.00
Mexico	48,586	2.77
Mozambique	17,329	0.99
Myanmar	28,856	1.64
Papua New Guinea	36,000	2.05
Peru	67,906	3.87
Tanzania	33,555	1.91
Sudan	42,976	2.45
Venezuela	45,690	2.60
Zaire	113,275	6.45
Zambia	32,301	1.84
TOTAL 'S' REGION	1,441,325	82.07
WORLD	1,756,299	100.00

Source: World Resources Institute (1994)

Table 2: Production Data Used in the Model

	North	South
1990 GDP (Billion US dollars)	20,942	1,387
Discounted 1990-2090 GDP (Billion US dollars)	800,551	92,954

Table 3: Model Parameters

	North	South
Calibrated share parameters		
Imports in tradeables demand	0.037	0.246
Non-tradeables in aggregate demand	0.681	0.473
Intra-regional trade in total trade	0.941	0.046
Substitution elasticities		
Armington trade elasticities (σ)	2.0	2.0
Tradeables-nontradeables substitution in consumption	1.0	1.0
Environment-using input-value added substitution	1.0	1.0

half of the North's GDP. The annual average depletion rate of tropical forests during the period 1981-90 was 0.6% (World Resources Institute, 1994). Assuming constant depletion and a quadratic damage function, we obtain an estimate of physical damage for our period of analysis. We impute a valuation for this damage by using an annual OECD income growth of 2.5% over the period as well as an elasticity of marginal valuation of tropical forests with respect to income equal to 1.25 (consistent with estimates obtained by Kramer et al., 1993). We obtain a Northern present value of the stream of environmental damage[7] for the 100-year model period using a 5% discount rate. These calculations are sensitive to parameter assumptions and in particular to the assumed damage function; on the other hand, there exist other important aspects of environmental damage (such as loss of biodiversity) which are omitted from this calculation. Our estimate of the valuation of base-case environmental damage associated with a business as usual scenario involves approximately a 60% depletion of Southern environmental assets, which we have the North valuing at 10% of its income over the period.

By choice of units we are able to set the marginal existence value of the North (v^N) equal to unity. The South's existence value of environmental assets is calculated as follows. The North's per capita GDP is about 6.3 times the South's, and the

[7]We interprete this as a willingness to pay measure. Haneman (1991, 1997) emphasizes the importance of income effects in yielding significant differences between willingness to pay and willingness to accept measures of environmental damage. We are greatful to V. Kerry Smith for raising this point.

Table 4: Parameters Used in the Environment Submodel

	North	South
Overall environmental damage*	n/a	0.10
Damage coefficients		
Tradeables	n/a	0.22
Non-tradeables	n/a	0.06
Elasticity of marginal valuation		
with respect to income	1.25	1.25

n/a: not applicable

* as a proportion of North's GDP

South's population is approximately 0.4 that of the North. Using again an elasticity of marginal valuation with respect to income of 1.25, and adjusting for population size, we arrive at an estimate of approximately 0.04 (relative to the North), the value for v^S used in our experiments with the model. Table 4 presents the basic data used for the environmental part of the model.

5 Simulations and Results

We have used the model parameterized following the calibration procedures we describe and the projected data for the period 1990-2090 to analyze the implications for developing countries of a linked trade and environment negotiation. We use this structure to first compute non-cooperative Nash equilibria of a tariff game (the disagreement point). Because of their relatively small size, developing countries are at disadvantage relative to the North in this noncooperative equilibrium. A bargained trade outcome improves the developing country situation a little relative to the disagreement point, but significant trade barriers remain against developing countries. In contrast, a linked trade and environment bargained outcome, where bargaining involves both trade and environmental policies, helps developing countries since they can use their leverage in environmental policy (given the relatively high existence value in the North) to help reduce Northern trade barriers against them.

These features emerge strongly from our central case set of model results summarized in Table 5. Here we have taken the central case model specification summarized above and computed non-cooperative Nash equilibria in tariffs, bargained outcomes in trade (tariffs), and joint bargained outcomes covering both trade and environment policies. Trade elasticities are critical parameters in determining outcomes, and in this specification we have used values of 2 for both North and South. As is well known, as these values approach unity, in a symmetric case both regions optimal tariffs would become large, and values significantly in excess of unity need to be used to avoid numerical problems. Because the asymmetries in size in our model can lead to large tariffs and associated numerical problems, we use an upper bound of 500% for tariffs in both regions in computing model solutions.

In the central case noncooperative equilibrium (first column of Table 5) the South's internalization rate is close to zero, consistent with most of the utility loss from lowered environmental quality being borne by the North. The North's trade barriers reach the upper bound of 500%, while the South's noncooperative tariff rate is around

Table 5: Central Case Model Results

	Scenario		
	Non-cooperative equilibrium	Bargaining over trade	Bargaining over trade and environment
Tariff rates (%)			
North	500.00	253.63	0.0
South	101.03	0.0	47.68
Environmental internalization rate (%)*			
North	0.0	0.0	0.0
South	0.41	0.41	54.10
Hicksian equivalent variation (% of GDP)			
A. With respect to disagreement point			
North	0.0	0.57	6.53
South	0.0	2.54	6.87
B. With respect to zero taxes and tariffs			
North	0.27	0.84	6.79
South	-8.89	-6.35	-2.02

* ratio of emission tax to marginal emission damage

100%. This difference in noncooperative tariff levels reflects both differences in country size and the fact that under zero environmental internalization in the South, the North employs tariffs as a second-best environmental policy instrument. The South's loss from a trade war is close to 9% of GDP, whereas the North gains a little relative to a free-trade, zero-internalization scenario.

An environment-only negotiation (not shown) in the absence of lump-sum side payments, has negligible impacts because of the strongly asymmetric pattern of abatement costs and benefits. Bargaining over trade policies in the absence of side payments (column two of Table 5) leads to an elimination of tariffs in the South and lowers tariffs in the North to around 250%. This generates substantial gains in the South (2.54% of GDP), which are significantly smaller than the almost 9.0% loss experienced by the South under tariff retaliation.

In contrast, combining trade and environmental policies in a joint negotiation makes it possible to sustain a level of internalization in excess of 50%, and leads to the total elimination of tariffs in the North. Some trade barriers remain in the South, as a "concession" by the North in exchange for the higher internalization rate. In this outcome the South's gains in relation to a noncooperative outcome are considerable—almost 7% of GDP, and a linked trade and environment negotiation is an attractive proposition to them.

As pointed out earlier, we can alternatively think of cooperation as reflecting tacit collusion in an infinitely repeated game,[8] where players maintain a cooperative

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[8]For an application of this approach to trade cooperation, see, for example, Bagwell and Staiger

stance if the gains from unilateral defection are less than the discounted gains from cooperation. By computing payoffs for the various players under cooperation, noncooperation, and for unilateral deviations from cooperation, we could characterize the maximum discount rate for which the threat of future punishment is effective as an inducement to cooperate. To explore how linkage of trade and environment dimensions affects the viability of cooperation, we could compare the maximum discount values obtained for scenarios where dimensions of strategic interaction are considered in isolation and where they are examined jointly. Given the regional asymmetries in trade and environmental costs and benefits, without side payments it would never be possible to sustain any form of cooperation in this model that is consistent with Pareto optimality, either in environmental policies or in trade policies, independently of whether they are combined.

With explicit bargaining and lump-sum side payments (Table 6), on the other hand, it is possible to achieve a first-best outcome with zero tariffs and 100% internalization. Introducing side payments overwhelmingly benefits the South, whose gains more than double as a result. Compared to a situation with no intervention, with cash transfers the South ends up with welfare gains which are high and not that different from those of the North, even though Southern preferences for environmental quality are much weaker than Northern ones. Thus, compared to a negotiation involving cash compensation for environmental restraint, the South gains far less from a linked trade and environment negotiation. A linked trade and environment

(1993).

Table 6: Trade and Environment Bargaining with and without Side Payments
Hicksian equivalent variations relative to zero taxes and tariffs (% of GDP)

	Scenario	
	Central case	Bargaining with side payments
North	6.79	6.89
South	-2.02	5.11

Note: with side payments, tariff rates are equal to zero, and the environmental internalization rate is equal to 100%

negotiation may be preferred to a trade-only negotiation, but may still be the wrong negotiation so far as the South is concerned.

We have also performed sensitivity analysis of our central case results to the Armington elasticity values we use. These suggest that an increase in trade elasticities to a value of 3 (Table 7), which makes trade retaliation less damaging for the South, weakens opportunities for negotiation linkage. As a result, the maximum level of internalization that can be achieved through linkage is reduced. Results in Table 7 also show that, when linkage is weakened through higher trade elasticities, a linked negotiation can make the South worse off in comparison with a trade policy-only bargained outcome—a finding not inconsistent with the comparative statics properties of Nash bargaining solutions. On the other hand, a reduction in trade elasticities (third column of Table 7) strengthens the potential for environment-trade policy negotiation linkages, and makes it possible to achieve a level of internalization close to 100% even in the absence of side payments.

Table 8 reports sensitivity analyses to model parameters affecting the size of damage and Northern existence value. When we decrease the level of damage (second column of Table 8), the noncooperative level of tariffs (not shown) in the North is reduced. This is because the presence of environmental externalities in tradeables production in the South generates an additional incentive for the North to curtail trade, beyond the standard terms-of-trade large-country motive. In other words, the presence of externalities induces the North to use trade policy as a substitute for environmental policy. As externalities are reduced, so is the North's optimal tariff. Negotiation linkage, however, remains strong. For higher levels of damage (third column of Table 8), negotiation linkages become stronger as the North increases its optimal tariff if the South does nothing to improve environmental quality. On the other hand, a lower marginal valuation of damage by the North (last column of Table 8) has effects qualitatively similar to those of reducing the assumed level of damage, with negotiation linkages remaining important, especially for the North.

5 Concluding Remarks

This paper addresses the issue of whether developing countries should participate in linked trade and environment negotiations in the WTO over the next few decades. We develop a small dimensional global simulation model capturing both North-South trade, and Southern use of environmental assets in trade-related production when

Table 7: Sensitivity Analyses to Model Parameters on Trade Elasticities (σ)
Hicksian equivalent variations relative to zero taxes and tariffs (% of GDP)

	Scenario		
	$\sigma = 2$ (Central case)	$\sigma = 3$	$\sigma = 1.25$
A. Non-cooperative equilibrium			
North	0.27	0.24	0.11
South	-8.89	-6.13	-11.98
B. Bargaining over tariffs			
North	0.84	0.50	1.76
South	-6.35	-0.72	-10.14
C. Bargaining over tariffs and env. policies			
North	6.79	6.17	7.18
South	-2.02	-1.78	-4.94

Table 8: Sensitivity Analyses to Model Parameters on Damage and Existence Value
Hicksian equivalent variations relative to zero taxes and tariffs (% of GDP)

	Scenario			
Damage*	0.10	0.075	0.125	0.10
North's existence value	1	1	1	0.5
	(Central case)			
A. Non-cooperative equilibrium				
North	0.27	0.05	0.59	-0.02
South	-8.89	-4.61	-8.87	-4.88
B. Bargaining over tariffs				
North	0.84	0.46	1.22	0.44
South	-6.35	-3.72	-7.61	-3.75
C. Bargaining over tariffs and env. policies				
North	6.79	4.43	8.41	2.84
South	-2.02	-2.72	-1.85	-2.85

* as a proportion of North's GDP

there is a high Northern existence value on such assets. We calibrate our model to data over a projected 100-year period from 1990 to 2090, in which Southern countries are identified as those accounting for 80% of tropical assets (forest, species). We compute various model solutions for alternative scenarios, principally noncooperative Nash equilibria for tariff games which serve as threat points for cooperative bargaining (again Nash) solutions, and similar solutions for linked trade (tariffs) and environmental (taxes) policy games.

In our central case analysis, linking trade and environmental policies in a joint negotiation expands the bargaining set and offers Southern developing countries an opportunity to exert discipline over Northern trade measures by making environmental concessions. The South thus benefits from a linked negotiation compared to a stand alone trade negotiation. However, in a negotiation with side payments, the South gains considerably more, suggesting developing countries should negotiate over cash for environmental restraint rather than indirectly on trade and environmental policy instruments. Sensitivity analysis suggests that as trade elasticities increase, and optimal stand alone tariffs fall, the benefits of linkage fall to the point that Southern countries benefit from being shielded from a trade and environment negotiation. Indeed, we report cases where linked negotiations can be detrimental to the South, but this is not true in our central case.

While model results are suggestive, our model parameterization is heroic, and there are missing features, reflecting developing country concerns over trade and environment linkage, which are not captured here. Trade and environment linkage could become the precedent for further wider linkage in trade negotiations, should developing countries agree to participate (trade and labour standard, for instance). Agreeing to the use of trade measures on environmental grounds would weaken the MFN principle in GATT/WTO, so central to developing country interests in the trading system. There is also ambiguity as to whether a cohesive Southern coalition can really be formed to participate in such a negotiation. Furthermore, cooperation in the GATT-WTO may not reflect a bargained agreement (which in the absence of a supranational authority would effectively not be enforceable) but rather a noncooperative equilibrium supported by implicit triggered retaliation threats, which the agreement only serves to ratify ex post. Under this interpretation, introducing an environmental dimension alongside trade negotiations may inject instability into the system, especially if policies are not observable (Riezman, 1991), and make retaliatory episodes more likely.

At the end of the day, however, the theme of our paper remains. Linked trade and environment negotiations in the WTO not only pose threats to developing country interests, they also create opportunities to improve trade disciplines over developed countries by trading off environmental concessions. These opportunities come with qualification, but seem worth close examination by them.

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