1998

The Effects of Collusion and Limited Liability on the Design of International Environmental Agreements for Developing Countries

Amitrajeet A. Batabyal
Utah State University

Follow this and additional works at: https://digitalcommons.usu.edu/eri

Recommended Citation
https://digitalcommons.usu.edu/eri/150
Economic Research Institute Study Paper

ERI #98-12

THE EFFECTS OF COLLUSION AND LIMITED LIABILITY ON THE DESIGN OF INTERNATIONAL ENVIRONMENTAL AGREEMENTS FOR DEVELOPING COUNTRIES

by

AMITRAJEET A. BATABYAL

Department of Economics
Utah State University
3530 Old Main Hill
Logan, UT 84322-3530

December 1998
THE EFFECTS OF COLLUSION AND LIMITED LIABILITY
ON THE DESIGN OF INTERNATIONAL ENVIRONMENTAL
AGREEMENTS FOR DEVELOPING COUNTRIES

Amitrajeet A. Batabyal, Associate Professor
Department of Economics
Utah State University
3530 Old Main Hill
Logan, UT 84322-3530

The analyses and views reported in this paper are those of the author(s). They are not necessarily endorsed by the Department of Economics or by Utah State University.

Utah State University is committed to the policy that all persons shall have equal access to its programs and employment without regard to race, color, creed, religion, national origin, sex, age, marital status, disability, public assistance status, veteran status, or sexual orientation.

Information on other titles in this series may be obtained from: Department of Economics, Utah State University, 3530 Old Main Hill, Logan, Utah 84322-3530.

Copyright © 1998 by Amitrajeet A. Batabyal. All rights reserved. Readers may make verbatim copies of this document for noncommercial purposes by any means, provided that this copyright notice appears on all such copies.
THE EFFECTS OF COLLUSION AND LIMITED LIABILITY ON THE DESIGN OF INTERNATIONAL ENVIRONMENTAL AGREEMENTS FOR DEVELOPING COUNTRIES

Amitrajeet A. Batabyal

ABSTRACT

In the 1992 Rio Earth Summit, developing countries (DCs) were adamant that in order to protect the environment for the future, new institutions were needed which would channel resources from the wealthy developed countries to the poor DCs. With this backdrop, I analyze the problem faced by an imperfectly informed supra-national governmental authority (SNGA) with limited financial resources which wishes to design an International Environmental Agreement (IEA). The SNGA cannot contract directly with polluting firms in the various DCs; it must deal with such firms through their governments. I study this tripartite hierarchical interaction and focus on the properties of the optimal limited liability IEA, which can be implemented by the SNGA when governments and firms in the individual DCs collude. I show that obtaining voluntary participation and preventing \textit{ex post} breach of contract is costly for the SNGA. Further, because the optimal IEA satisfies budget balance, the level and pattern of pollution abatement is typically not ideal. My analysis suggests that IEAs are not inherently doomed due to a basic monitoring and enforcement problem arising from national sovereignty. However, the success of IEAs is fundamentally contingent on the funds available for environmental protection.

\textit{JEL} Classification: Q25, H77, D82

Key words: international environmental agreement, developing country, limited liability
THE EFFECTS OF COLLUSION AND LIMITED LIABILITY
ON THE DESIGN OF INTERNATIONAL ENVIRONMENTAL
AGREEMENTS FOR DEVELOPING COUNTRIES

1. Introduction

With the passage of time, it has increasingly been recognized that environmental protection is an international issue. As noted by Bernauer (1995, p. 354), the scope and significance of this issue have been amply demonstrated by the events of the 1992 Earth Summit in Rio. At this Summit, it became clear that if the developed countries of the world wanted “... the environment to be secured for future generations, [then they would] have to radically assist the South in choosing a different road to development than the one they [had] currently [been] traveling on” (Rogers 1993, p. 27). Indeed, to combat the twin evils of poverty and environmental degradation, developing countries (DCs) have demanded the transfer of resources and technology from developed countries. In such a contentious setting, the success or failure to protect the environment will depend crucially on the ability of international institutions to craft effective international environmental agreements (IEAs). Given this, a key question becomes “How can international institutions, which necessarily respect the principle of state sovereignty, contribute to the solution of difficult global problems?” (Keohane, Haas, and Levy 1993, p. 6). This is the central question that I propose to analyze in this paper.

1 I acknowledge financial support from the Utah Agricultural Experiment Station, Utah State University, Logan, UT 84322-4810, by way of project UTA 024. This paper has benefitted from the comments of seminar participants at the College of William and Mary and at the University of California, Berkeley. The usual disclaimer applies.

2 In this paper I shall use the terms IEA and contract interchangeably.
On the academic front, researchers have begun to study issues relating to global environmental protection in a systematic manner only very recently. As a result, many specific questions remain unanswered. What kinds of pollution abatement patterns can one expect to observe in economic environments in which an imperfectly informed supranational governmental authority (SNGA) contracts with governments and polluting firms in individual DCs? What kinds of monetary transfers will be needed to get sovereign nations to voluntarily participate in an IEA? What can the SNGA do to prevent sovereign nations from breaching contracts they had agreed to ex ante? How does the SNGA’s inability to monitor pollution abatement in the individual countries affect the contract design question? Finally, how does the limited availability of funds affect the SNGA’s IEA design question? These are the specific questions that I shall answer in this paper.

Although my analysis is, in principle, applicable to any country, the hierarchical interaction that I shall analyze is particularly relevant to DCs; consequently, the reader should note that it is these countries that I have in mind in all of the subsequent analysis. I now discuss the nascent literature on IEAs and then move on to discuss my model in detail.

---

3 See Bernauer (1995), and Keohane, Haas, and Levy (1993) for a more detailed corroboration of this claim.

4 By ex ante I mean contracting which takes place with all parties holding symmetric but imperfect information about the quality of the pollution abatement technology of firms. By ex post I mean contracting which takes place with the players holding asymmetric information about the quality of the pollution abatement technology of the same firms.

5 The countries I have in mind are those that would be eligible to receive monetary transfers under the Global Environmental Facility’s (GEF) standard of per capita income of $4,000 or less. For more details, see Rogers (1993, p. 155).
2. International Environmental Agreements:

A Brief Synopsis

Barrett (1992; 1994) has modeled IEAs as games between different countries. While Barrett’s analyses are not in the design framework, Barrett makes the important point that for IEAs to work, they must be self-enforcing. However, the thrust of this point is weakened by Barrett’s focus on identical countries, with no uncertainty. As a result, this line of research is unable to address fundamental questions arising from imperfectly held information and the heterogeneity of the contracting countries.

Hoel (1991; 1992) addresses the implications of, in turn, unilateral emissions reduction by countries, and uniform emissions reduction by all countries. Hoel (1991, p. 69) shows that unilateral actions “... may ... reduce global welfare ...” by increasing the total emissions of pollutants. Hoel (1992) argues against the institution of uniform emissions reduction policies in international agreements, showing that other policies yield higher levels of global welfare.

Shogren, Baik, and Crocker (1992, SBC), Black, Levi, and de Meza (1993, BLD), and Sandler and Sargent (1995, SS) have all addressed the question of the minimal number of countries needed to sustain an IEA. In a multiplayer strategic setting, SBC show that countries will sometimes join IEAs because the expected gains from such an action outweigh the gains from not joining. However, beyond a critical threshold value, some countries will prefer to free ride and not join the IEA, whereas the IEA members will want nonparticipants to join. BLD have explored this notion of a threshold value, which they call “the optimal ratification level.” BLD show that this level is reasonably robust to variations in contractual circumstances; more significantly, BLD argue that the prospects for effecting an IEA are not necessarily diminished by there being a large number of
countries. SS (1995, p. 152) show that the attainment of international coordination by a "minimal-sized group" is fundamentally dependent on "... how individual pollution activities add to the total pollutants experienced ... [by nations]." While these papers have certainly advanced our understanding of some aspects of "... the multi-faceted design ... problem," (BLD, p. 281), many other important questions—which I discussed in section 1—remain unanswered. Consequently, I now discuss my modeling approach to the IEA design question.

Recall that my principal objective is to study the efficacy of international institutions in solving global environmental problems. To this end, I shall model the international environment as a multiforked, three-tiered hierarchy. Occupying the topmost tier of the hierarchy is the relevant international institution or SNGA. This SNGA could be an organization like the World Bank,6 or the Commission on Sustainable Development created in Agenda 21 at the Rio Earth Summit. The second and third tiers of the hierarchy consist of the government and a representative polluting firm in each DC. Each fork of the hierarchy corresponds to a single DC, and there are \( N \) such countries.7

Three-tiered hierarchies have been studied by Tirole (1986; 1988), by Kofman and Lawarree (1993), and by Batabyal (1996a; 1996b). These researchers have studied the contractual effects of collusion between the various players in their three-tiered hierarchies. However, to the best of my knowledge, the problem of designing budget balanced, limited liability contracts in a hierarchical international setting has not been studied to date.

---

6Specifically in its role as an administrator of the Global Environmental Facility (GEF).

7The reader will note that in this modeling scheme, I have conferred on the SNGA, the role of principal. Consequently, there is a distinct asymmetry in the assumed power of the SNGA as opposed to that of governments and firms. Given that I am interested in DCs, which typically have limited bargaining power in their dealings with international organizations owing to the fact that their monetary contributions to the budgets of such organizations are minimal, this hierarchical modeling scheme appears to be appropriate. For more on the power of SNGAs over DCs, see Mosley, Harrigan, and Toye (1991).
As such, I shall build on and apply the theory of hierarchies to study *ex ante*, limited liability contracting between the SNGA, national governments, and polluting firms in the various DCs. By limited liability I mean contracts that impose limits on the maximum *ex post* loss that governments and firms in the individual DCs can be forced to bear as a result of pollution abatement in adverse states of nature. This feature of the IEA that I shall study would appear to be relevant because international institutions generally cannot guarantee that there will be no *ex post* breach of contract by nations. The rationale for the actual contracting stems from issues including, but not limited to, the harmful atmospheric effects of sulphur and/or nitrogen emissions. The incidence of pollution may be domestic or transboundary.\(^8\) The key element of uncertainty stems from the SNGA’s lack of knowledge about the *quality* of the pollution abatement technology available in each country. Whereas the firm in the DC always knows the quality of its technology and the government does in some states of nature, the SNGA is never privy to this information. The random variable denoting the private information about pollution abatement technology quality is uncorrelated across countries. This rules out the possibility of the SNGA engaging in relative performance evaluation. Because most DCs are very heterogeneous, and because it is unlikely that a SNGA would want to design contracts involving relative performance evaluation, this assumption of uncorrelatedness appears not to be restrictive.\(^9\) In other words, my analysis holds for any finite set of countries, with the SNGA/government/firm interaction in one country being independent of the SNGA’s dealings with some other country. Consequently, without loss of generality, I shall focus on an arbitrary country, say country \(j\), in the finite set of countries. The SNGA’s task is to design a limited liability

\(^8\)See Crane (1993) and Paarlberg (1993) for a discussion of the relevance of international institutions when the incidence of an environmental externality is domestic.

\(^9\)Batabyal (1996c) has analyzed contracting with relative performance evaluation.
IEA which is incentive compatible, collusion-proof, and which will lead to optimal pollution abatement in country $j$.

The rest of this paper is organized as follows. In section 3, I describe the model in detail and I study the properties of the first best optimum. In section 4, I study the above-described three-tiered hierarchy in which governments and firms within a DC may collude to the detriment of the SNGA. In particular, I analyze an *ex ante*, limited liability contract, which can be implemented by the SNGA in a Bayes-Nash equilibrium. Finally in section 5, I summarize the salient findings of this paper.

The reasons for wanting to study collusion between the polluting firm and the DC government are threefold. First, while the DC government participates in the IEA because it recognizes the value of such international participation, this government also acts as the polluting firm’s advocate. This aspect of the problem will give rise to scenarios in which government/firm collusion becomes a desirable option. Second, the government and the firm receive monetary transfers from the SNGA for their roles in abating pollution. Further, both these players know that the SNGA cannot monitor their activities owing to sovereignty. Consequently, there will be circumstances in which there are incentives for the government and the firm in each country to collude to maximize the transfers received from the SNGA. Third, as Mookherjee and Png (1995) noted, corruption is an endemic part of public life in many DCs. This suggests a need for explicitly modeling the activities of potentially corruptible players. Due to these three reasons, an important part of this paper will consist of analyzing a collusion-proof IEA.

---

10 See Peterson (1993) for a discussion of some practical instances of possible government/firm collusion in an international setting.

11 The exact nature of these roles is described in section 3a.
3. The Theoretical Framework

3a. Description of the Model

Subscript \( i = 1, 2, 3, 4 \) will refer to the state of nature, and superscript \( j = 1, \ldots, N \) will refer to the country. Let \( \theta \) denote the uncertainty about the quality of the abatement technology that is currently available; \( \theta \) has binary support \( [\theta_L, \theta_H] \), where \( 0 < \theta_L < \theta_H \), and \( \Delta \theta = \theta_H - \theta_L \). I shall refer to \( \theta_L \) as the low abatement quality parameter and to \( \theta_H \) as the high abatement quality parameter.

The risk-averse firm produces clean air, whose output and value are denoted by \( x = a + \theta, \, x \in \mathbb{R} \). The firm chooses pollution abatement \( a \in \mathbb{R} \), and the firm’s cost of abatement is \( g(a) \), where \( g'(\bullet) > 0 \), \( g''(\bullet) > 0 \), and \( g(0) = 0 \). This firm has a differentiable net payoff from abatement function \( B[T_i - g(a_i)] \) with \( \frac{\partial B[\bullet]}{\partial T_i}(0, \infty) \), \( \forall T_i \). \( T_i \in \mathbb{R} \) is the state \( i \) monetary transfer made by the SNGA to the firm for abating pollution. The firm’s reservation payoff is \( B_r = B[T_r] \), and \( T_r \) is the reservation transfer. \( B \), and \( T \), are common knowledge.

The DC government is risk-averse. It has a strictly concave and differentiable utility function \( V(G_i) \), where \( G_i \in \mathbb{R} \) is the state \( i \) monetary transfer made by the SNGA to the government for its role in participating in the IEA. The government’s reservation utility is \( V_r = V(G_r) \), where \( G_r \in \mathbb{R} \) is the reservation transfer, and \( V'(G_i) \in (0, \infty), \forall G_i \). By employing a monitoring device, the government receives a signal \( s \), from the firm regarding its private information and then it sends a report \( r \) to the SNGA, indicating what it observed about the firm’s pollution abatement technology quality parameter.\(^{12}\) In some states of nature, this monitoring device malfunctions and, hence, in these states, the government will be unable to provide the SNGA with an useful report. Upon

---

\(^{12}\)Since the main objective of this paper is not to study domestic monitoring, I shall assume that the use of this monitoring device is costless.
receiving $r$, the SNGA offers the government a transfer $G_i \in \mathbb{R}$. The reader should note that making reporting a key government function is consistent with the government/SNGA interaction proposed for one specific SNGA, namely, the Commission on Sustainable Development. As noted by Rogers (1993, p. 310), a key aspect of this interaction involves the “... Commission’s ... considering information provided by governments ...”

The SNGA is risk-neutral, and it has a welfare function defined over clean air, which takes the form $U = \sum_j (a_j + \theta^j - G^j - T^j)$, $j = 1, \ldots, N$, where the index $j$ runs over $N$, the total number of countries. The quantity of clean air produced by the firm in country $j$ is $x^j = a^j + \theta^j$. As stated, the SNGA’s welfare is the difference between total clean air production and the sum of government and firm transfers. In what follows, when there is no cause for confusion, I shall suppress the country superscript; the analysis will focus on country $j$. The SNGA designs the IEA, which it offers to the government and the firm. The contract can only be conditioned on what the SNGA actually observes, i.e., the government’s report $r$, and the firm’s production of clean air $x$.\(^{13}\)

There are four states of nature, each state occurring with probability $p_i > 0$, where $\sum_i p_i = 1$. The SNGA, the government, and the firm sign the IEA holding symmetric but imperfect information about $\theta$. The firm always observes $\theta$ before choosing its abatement level. The government, on the other hand, may or may not observe the firm’s private information. This depends on whether the government’s monitoring device functions or malfunctions. In other words, the government’s signal $s$, may or may not be informative. I can now characterize the four states:

* State 1: The firm and the government both observe $\theta^j$.

---

\(^{13}\)I do not discuss the manner in which the SNGA raises revenue. One possibility would be to conform to the text of Agenda 21. According to this document, developed countries are supposed to contribute 0.7% of their GNP for the purpose of environmental protection. For more details, see Rogers (1993, pp. 151-60).
State 2: The firm observes $\theta^L$ and the government observes nothing.

State 3: The firm observes $\theta^H$ and the government observes nothing.

State 4: The firm and the government both observe $\theta^H$.

In state 1, the firm and the government both observe the low abatement technology quality parameter. The government’s monitoring device works and, hence, yields useful information. In state 2, the firm observes the low abatement technology quality parameter but the government observes nothing. In this state, the government’s monitoring device malfunctions. In state 3, the firm observes the high abatement technology quality parameter, and, once again, the government’s monitoring device malfunctions. Finally in state 4, the firm and the government observe the high abatement technology quality parameter.

The timing of the game between the SNGA, the government, and the firm is as follows. First, the SNGA offers a contract to the government and the firm. Second, the firm observes the actual realization of $\theta$ and the government receives its signal $s$. Third, the firm chooses $a$. Fourth, clean air $x$ is produced by the firm, and the government sends its report $r$ to the SNGA, indicating what it observed. Fifth, the SNGA compensates the government and the firm with transfers $G(x, r)$ and $T(x, r)$. In this paper, I shall analyze zero liability contracts. In such contracts, the SNGA must compensate governments and firms with transfers equal in magnitude to the government reservation utility and the firm reservation payoff, respectively. Alternately put, in such contracts, governments and firms have the right to disassociate themselves from their ex ante contractual obligations without any penalty, once they have acquired their private information. For most practical situations, this zero liability restriction is without loss of generality. Indeed, my subsequent analysis will remain
unaltered qualitatively as long as the magnitudes of the government and firm liabilities—\(L_G\) and \(L_F\), respectively—are less than the government reservation utility, and the firm reservation payoff.\(^{14}\)

In the remainder of this paper I shall assume that the SNGA can verify the veracity of the government’s report \(r\). In other words, if the government’s signal \(s\) is noninformative, then the corresponding report \(r\) reflects this fact, and the SNGA can verify that the true facts are indeed as they have been reported. In symbols, \(s = 0 \rightarrow r = 0\). On the other hand, to keep the SNGA’s design problem interesting and to allow for the possibility of government/firm collusion, I permit the government to lie and report that its signal is noninformative when in fact such is not the case.\(^{15}\) That is, \(s = 0 \rightarrow r \in \{0, 0\}\). This completes the description of my model. I now consider the benchmark case in which perfect information is acquired by the SNGA.

3b. The First-Best Optimum

In this case, the SNGA observes \(\theta\) and the firm’s pollution abatement choice. When this happens, the SNGA bypasses the government and contracts with the firm directly. The government receives its reservation transfer, \(G_r\), and, hence, its reservation utility, \(V_r\), in all states. The SNGA solves

\[
\max_{a_i} \sum_i \{ a_i + \theta_i - g_i(a_i) - T_{r_i} - G_{r_i} \},
\]

\(\text{(A)}\)

\(^{14}\)In a two-tiered hierarchy, Sappington (1983, pp. 15-7) discusses how zero liability contracts would be altered by restrictions in which a player’s liability exceeds his reservation utility.

\(^{15}\)The reader will note that I have restricted the government’s message space in certain states. Specifically, the government can lie only in states 1 and 4. The government can also announce the wrong state, but in my setup, this is equivalent to obtaining a noninformative signal. While in principle this restriction can be relaxed by allowing for an expanded range of governmental reporting options, from a practical standpoint, such an action would make it exceedingly difficult to obtain concrete results. This is because relaxing the above restriction would lead to an increased number of states and, hence, to more constraints on the SNGA’s overall optimization problem.
subject to (A1) \[ \sum_{i} p_i B[T_i - g(a_i)] \geq B_r, \] (A2) \[ B[T_i - g(a_i)] \geq L_f, \forall i, \] and (A3) \[ \dot{M} \geq \sum_{j} \{ T_r^j + g^j(a^*_j) + G^j \}. \]

Because I am analyzing a zero liability contract, \( B_r = L_f \), and, hence, the firm’s \textit{ex ante} participation constraint (A1) can be ignored. Now using the fact that the zero liability constraints in (A2) bind, the first-order necessary conditions are \( dg^j(a_j)/da_j = 1/(1 + \gamma), \forall i, j \), where \( \gamma \) is the multiplier on the budget balance constraint (A3) and \( a^* \) is the first-best level of pollution abatement. We see that in the first-best optimum, the marginal cost of pollution abatement in country \( j \) is set equal to the reciprocal of one plus the marginal welfare of the SNGA’s funds. The optimal level of abatement \( a^* \) is independent of the state; consequently, the firm’s transfer for abating pollution is also independent of the state. This transfer equals \( T_r + g^* \), where \( T_r \) is the reservation transfer and \( g^* = g(a^*_r) \).

It is not possible to determine whether the SNGA’s budget constraint binds in equilibrium. To see why not, note the following. The SNGA’s welfare function exhibits constant marginal welfare in the authority’s own funds. As opposed to this, the funds spent making transfers do not exhibit constant marginal welfare. As a result, it is possible that, in equilibrium, the SNGA will disburse only a part of \( \dot{M} \) because the effect of such disbursement on clean air production drops below one before the SNGA exhausts \( \dot{M} \). The second case in which the SNGA exhausts \( \dot{M} \) before the effect on clean air production drops below one is also possible. Which case will prevail depends on the curvatures of the \( B^j[\bullet] \), and particularly the \( g^j(\bullet) \) functions. In the rest of this paper I shall assume that the curvatures of these two functions are such that the budget constraints bind in equilibrium. From a practical standpoint, this is the relevant case. I now discuss the more interesting case in which the DC government and the firm may collude, and the SNGA cannot observe \( \theta \) or the actual abatement undertaken by the firm.
4. The Effects of Collusion and Limited Liability

Recall that because countries are sovereign, the SNGA is unable to either monitor the actions of the government and the firm or enforce the terms of the IEA in the event of a contractual breach. Since the SNGA can never acquire the firm’s private information and must rely on the government’s report to design the optimal contract, an efficient zero liability contract must not only be individually rational and incentive compatible, but it must be collusion-proof as well.\(^\text{16}\)

I shall model collusion between the government and the firm as follows. Before the resolution of the uncertainty regarding abatement technology quality and at the time of signing the main contract, i.e., the SNGA/government/firm contract, the firm and the government sign a secondary contract, which entails the offer and acceptance of a bribe from the firm to its government. Naturally, this secondary contract is unobservable by the SNGA. The bribe \(b(\bullet, \bullet)\), is a function of what the firm and the government both observe, i.e., the government’s report \(r\), and clean air \(x\). With the offer and acceptance of this bribe, the firm’s total transfer becomes \(\{T(\bullet) - b(r, x)\}\) and the government’s total transfer becomes \(\{G(\bullet) + b(r, x)\}\). I shall not be concerned with the question of how the surplus from the bribe is divided. For my purpose, it is only necessary to stipulate that the bribe is actually paid by the firm to its government. To see why the firm might want to bribe its government in my four-state world, consider state 4. In state 4, the government is indifferent between reporting that it has observed \(\theta^H\) and reporting that it has observed 0. However, the firm would prefer that the government report 0. This is one instance in which a clear rationale exists for the firm to bribe its government.\(^\text{17}\)

---

\(^{16}\) Also see footnote 10.

\(^{17}\) Also see the discussion in the last paragraph of section 2.
In order to formulate and solve the SNGA’s problem when there is collusion, I shall follow Tirole (1986; 1988). Tirole’s method involves imposing constraints in addition to the usual participation and incentive compatibility constraints. These additional constraints are designed to preclude government/firm collusion and, hence, make the main contract collusion-proof.

Denote the collusion-proof transfers to the government and the firm by $G$ and $T$, respectively.

The SNGA solves

\[
\max_{\{\bar{G}_i, \bar{T}_i, a_j\}} \sum_{i} p_i (a_i + \theta_i - \bar{G}_i - \bar{T}_i)
\]

subject to (A1)-(A2) with $T_i$ and $G_i$ replaced with $\bar{T}_i$ and $\bar{G}_i$, (B1) $\sum_{i} p_i V(\bar{G}_i) \geq V_r$, (B2) $V(\bar{G}_i) \geq L_G$, $\forall i$, (B3) $\bar{T}_3 - g(a_3) \geq \bar{T}_2 - g(a_2 - \Delta \theta)$, (B4) $\bar{T}_2 - g(a_2) \geq \bar{T}_3 - g(a_3 + \Delta \theta)$, (B5) $\bar{G}_1 + \bar{T}_1 - g(a_1) \geq \bar{G}_2 + \bar{T}_2 - g(a_2)$, (B6) $\bar{G}_4 + \bar{T}_4 - g(a_4) \geq \bar{G}_3 + \bar{T}_3 - g(a_3)$, (B7) $\bar{G}_3 + \bar{T}_3 - g(a_3) \geq \bar{G}_2 + \bar{T}_2 - g(a_2 - \Delta \theta)$, (B8) $\bar{G}_2 + \bar{T}_2 - g(a_2) \geq \bar{G}_3 + \bar{T}_3 - g(a_3 + \Delta \theta)$, and (B9) $M \geq \sum_{i} (\bar{G}_i - \bar{T}_i)$, $\forall i$.

The constraint (B1) is the government’s *ex ante* participation constraint. The four constraints in (B2) denote the government’s zero liability constraints. These constraints can be interpreted as the maximum penalty that can be imposed on the government by the SNGA in the event that *ex post*, the government chooses to disassociate itself from its contractual obligations. Because I am studying zero liability contracts, $V_r = L_G$ and $B_r = L_F$. Constraints (B3) and (B4) are the firm’s incentive compatibility constraints. Constraint (B3) says that in state 3, the firm should not claim that the state is actually 2. Similarly, (B4) tells us that in state 2, the firm should not claim that the state is actually 3. Note that these are also the states in which the government’s signal $s$ is noninformative. Constraints (B5) and (B6) are the core collusion constraints. Recall that in states 1 and 4 the government’s signal $s$ is informative. In these two states, the government can hide this
fact. Given this, constraints (B5) and (B6) tell us that should the firm bribe its government, then the total sum of the transfers less the cost of pollution abatement in states 1 and 4 cannot be less than the corresponding totals in states 2 and 3, respectively. Constraint (B7) tells us that the government should not be able to bribe the firm in state 3 to abate at the level that is appropriate for state 2. Similarly, (B8) says that the government should not be able to bribe the firm to claim that the state is 3 when it is 2. Finally, (B9) denotes the SNGA’s budget constraints. These constraints tell us that irrespective of state, the total sum of transfers paid to the government and the firm in the various countries cannot exceed the SNGA’s available budget $\hat{M}$ for environmental protection. Solving the SNGA’s problem (B) subject to (A1)-(A2) and (B1)-(B9), I get

**Theorem 1:** The optimal zero liability contract when there is government/firm collusion is one in which

(i) $a_1 = (g')^{-1}\{p_1/(p_1 + \gamma_1)\}$, $i \neq 2$, $a_2 = (g')^{-1}\{p_2/(p_2 + \gamma_2)\} - D$,  

(ii) $\bar{A}_j g(a_j) = \bar{A}_3 g(a_3) = \bar{A}_4 g(a_4) > \bar{A}_2 g(a_2)$,  

(iii) $\bar{G}_4 > \bar{G}_i = \bar{G}_2 = \bar{G}_3 = G_r$,  

(iv) $\bar{T}_3 - g(a_3) > \bar{T}_4 - g(a_4) > \bar{T}_1 - g(a_1) = \bar{T}_2 - g(a_2)$, and (v) at the optimum all the constraints except (A1), (A2, $i = 1,2,3$), (B1), (B2, $i = 4$), (B4) and (B8) bind.\(^\text{18}\)

**Proof:** See the Appendix.

In order to intuitively verify that the above contract is collusion-proof, I have to show that constraints (A1)-(A2) and constraints (B1)-(B9) are satisfied. By part (v) of Theorem 1, constraints (A2, $i = 1,2$), (B2, $i = 1,2,3$), (B3), (B5), (B6), (B7) and (B9) are satisfied. The proof of Theorem 1 tells us that constraints (A1), (A2, $i = 3,4$), (B1), (B2, $i = 4$), (B4) and (B8) hold as strict inequalities. Thus the equilibrium contract is indeed collusion-proof. Let us now study this collusion-proof contract in greater detail.

\(^\text{18}\)For an exact representation of $\bar{A}_j$ and $D$, see the proof of Theorem 1 in the Appendix.
First, part (i) of Theorem 1 tells us that the actual level of pollution abatement in any state is a function of the state probability $p_i$ and the multiplier on the budget constraint $\gamma_i$. Part (ii) tells us that the optimal contract equalizes the weighted marginal cost of pollution abatement in states 1, 3, and 4. That is, $\tilde{A}_i g'(a_i) = \tilde{A}_j g'(a_j) = \tilde{A}_k g'(a_k) > \tilde{A}_l g'(a_l)$ holds, where $\tilde{A}_1, \ldots, \tilde{A}_4$ are weights. Because the budget constraints bind in equilibrium, the contractually specified levels of abatement will generally not be ideal. In this connection, the reader should note that because the expression for the first-best level of abatement $a_*$ in section 3b involves a multiplier $\gamma$ that is specific to the first-best problem, no direct comparison of the optimal abatement levels across the two modeling scenarios can be made.

Second, part (iii) of Theorem 1 tells us that the transfers to the DC government reflect the usefulness of the government's report to the SNGA. In particular, because the government’s report is noninformative to the SNGA in states 2 and 3, $\bar{G}_2 = \bar{G}_3 = G_r$ holds. Further, in order to prevent collusion and to encourage the government to tell the truth in the high abatement technology quality state 4, the SNGA offers $\bar{G}_4 > \bar{G}_2 = \bar{G}_3 = G_r$. The government earns no informational rents in the low abatement technology quality state 1 because the SNGA is successful in inducing the government to reveal its private information truthfully at least cost.

Third, parts (iv) and (v) of Theorem 1 tell us that at the optimum, the firm and the government liability constraints bind more often than not. This means that the optimal contract offered by the SNGA must respect the fact that ex post, the firm and the government may choose to disassociate themselves from their contractual obligations in several states of nature. To see why these liability constraints do not bind in every state of nature, consider the firm liability constraints

---

19 See step 13 of the proof of Theorem 1 for an exact representation of these weights.
for states 3 and 4. The state 3 liability constraint is slack because the incentive compatibility constraint for this state binds at the optimum. This simply reflects the fact that in this high abatement technology quality state, the incentive compatibility constraint (B3) is always more restrictive than the liability constraint. Similarly in state 4, as compared to the liability constraint, the collusion incentive compatibility constraint (B6) is more pressing to the SNGA. In particular, in order to ensure that no collusion takes place in this high abatement technology quality state, the SNGA has to pay a premium to the firm. This is why the state 4 firm liability constraint is slack at the optimum.

Note that as compared to the case in which the government and the firm do not collude, the SNGA is clearly worse off in this collusion case. This is because the possibility of government/firm collusion necessitates the inclusion of constraints (B5)-(B8). In other words, the number of binding constraints in the collusion case exceeds the number of binding constraints in the no collusion case. However, if the SNGA does indeed offer the contract with the characteristics described in Theorem 1, then its monetary obligations will be as described in the Theorem. The reader should note that the SNGA offers the best contract possible from the set of feasible, zero liability contracts that are constrained to be budget balancing and collusion-proof.

5. Conclusions

In this paper I analyzed the question of environmental protection for developing countries within the framework of the directives set forth in the various agreements reached at the 1992 Rio Earth Summit. I modeled the institutional setting for the underlying problem as a three-tiered hierarchy with $N$ forks, and then I studied the effects of collusion and limited liability on the SNGA's IEA design problem. Four significant policy conclusions emerge.
First, the liability constraints for the government and the firm generally bind at the optimum. This means that from the perspective of the SNGA, it is costly to obtain voluntary participation by individual DCs and preventing \emph{ex post} breach of contract. This notwithstanding, Barrett (1994) has argued that for IEAs to work, they must be self-enforcing. Along the same lines, Rogers (1993, p. 236) has worried that many of the Earth Summit directives “... offer a back door option by which signatories can excuse themselves at a later date if the going gets too tough.” The implementability of limited liability contracts of the sort analyzed in this paper should allay such concerns because a limited liability contract is self-enforcing. Put differently, as compared to an \emph{ex ante} contract, a limited liability contract is more likely to be renegotiation-proof.

Second, money matters. Although one cannot be certain that budgetary considerations will have a qualitative impact on the contractually specified pollution abatement levels, it seems reasonable to suppose that in any practical setting, such considerations will influence actual pollution abatement patterns by limiting the magnitude of the transfers that a SNGA can make.

Third, the SNGA will prefer \emph{ex ante} contracting to contracting with limited liability constraints. Because \emph{ex ante} contracting involves optimization with fewer constraints, the SNGA’s expected welfare with \emph{ex ante} contracting will be higher than its expected welfare with limited liability contracting. However, in the context of DCs, unless a SNGA can limit the \emph{ex post} liability of the players, nations are unlikely to participate in \emph{ex ante} contracting schemes. Further, \emph{ex ante} contracting schemes will generally not be self-enforcing.

Fourth, the SNGA can indeed circumvent the monitoring and enforcement problem stemming from national sovereignty by designing collusion-proof contracts. This tells us that the concerns of researchers like Krasner (1983) who have worried about the deleterious effects of sovereignty, are
somewhat misplaced. At least in the realm of international environmental affairs, the main impediments to the design of efficient IEA's appear to involve funds and informational imperfections.

With talk of rising disparity between the South and the North and the increasingly acrimonious nature of international discussions regarding the use of environmental resources, the IEA design question studied in this paper takes on particular significance. This is in no small measure due to the fact that the implementation of such agreements will do more to engender and maintain international security than will most strategic or unilateral policy measures.
References


Appendix

**Proof of Theorem 1:** Because \( B_r = L_F \) and \( V_r = L_G \), (A1) and (B1) are redundant and can be ignored. Omitting (B4) and (B8) temporarily, the Lagrangian is

\[
\mathcal{L} = \sum_i p_i (x_i - \bar{G}_i - \bar{T}_i) + \sum_i \alpha_i \{ B[\bullet] - L_r \} + \sum_i \nu_i \{ V(\bullet) - L_G \} + \beta \{ \bar{T}_3 - g(\bullet) - \bar{T}_2 + g(\bullet) \} + \epsilon_i \{ \bar{G}_j + \bar{T}_j - g(\bullet) - \bar{G}_2 - \bar{T}_2 + g(\bullet) \} + \epsilon_2 \{ \bar{G}_4 + \bar{T}_4 - g(\bullet) - \bar{G}_3 - \bar{T}_3 + g(\bullet) \} + \kappa \{ \bar{G}_3 + \bar{T}_3 - g(\bullet) - \bar{G}_2 - \bar{T}_2 + g(\bullet) \} + \sum_i \gamma_i [\bar{M} - \sum_j \{ \bar{G}_i + \bar{T}_j \}],
\]

(b)

where \( \alpha_i, \nu_i, \beta, \epsilon_i, \kappa, \gamma_i, i = 1, 2, 3, 4, l = 1, 2 \) are the multipliers associated with (A2), (B2), (B3), (B5), (B6), (B7), and (B9), respectively. The first-order necessary conditions are (b1)

\[
u_i V'(\bar{G}_i) = p_i - \epsilon_i + \gamma_i, \quad (b2) \nu_3 V'(\bar{G}_3) = p_3 + \epsilon_2 - \kappa + \gamma_3, \quad (b4) \nu_4 V'(\bar{G}_4) = p_4 + \epsilon_2 + \gamma_4, \quad (b5) \alpha_1 \{ \partial B[\bullet]/\partial \bar{T}_1 \} = p_1 - \epsilon_1 + \gamma_1, \quad (b6) \alpha_2 \{ \partial B[\bullet]/\partial \bar{T}_2 \} = p_2 + \beta + \epsilon_1 + \kappa + \gamma_2, \quad (b7) \alpha_3 \{ \partial B[\bullet]/\partial \bar{T}_3 \} = p_3 + \epsilon_2 - \beta - \kappa + \gamma_3, \quad (b8) \alpha_4 \{ \partial B[\bullet]/\partial \bar{T}_4 \} = p_4 - \epsilon_2 + \gamma_4, \quad (b9) \{ \alpha_1 B'[\bullet] + \epsilon_1 \} g'(a_1) = p_1, \quad (b10) \{ \alpha_2 B'[\bullet] - \epsilon_2 \} g'(a_2) = p_2 + \{ \beta + \kappa \} g'(a_2 - \Delta \theta), \quad (b11) \{ \alpha_3 B'[\bullet] + \beta - \epsilon_2 + \kappa \} g'(a_3) = p_3, \quad \text{and} \quad (b12) \{ \alpha_4 B'[\bullet] + \epsilon_2 \} g'(a_4) = p_4.
\]

**Step 1:** The budget constraints bind at the optimum.

**Proof:** This result follows by assumption. Also see the related discussion in section 3b. □

**Step 2:** The state 2 firm and government liability constraints bind at the optimum.

**Proof:** Suppose \( \alpha_2 = 0 \). Then (b6) tells us that \( \gamma_2 = -(p_2 + \beta + \epsilon_1 + \kappa) \), which is impossible irrespective of whether \( \beta \geq 0, \epsilon_1 \geq 0, \) and \( \kappa \geq 0 \). Thus \( \alpha_2 > 0 \). Similarly, (b2) says that \( \nu_2 = 0 \Rightarrow \gamma_2 = -(p_2 + \epsilon_1 + \kappa) \), which is impossible irrespective of whether \( \epsilon_1 \geq 0 \) and \( \kappa \geq 0 \). Thus, \( \nu_2 > 0 \). □

**Step 3:** The state 1 firm and government liability constraints bind at the optimum.
Proof: (b1) tells us that $v_1 = \epsilon_1 = 0$ is impossible. (b1) and (b5) tell us that either (i) $\alpha_1 = v_1 = 0$ or (ii) $\alpha_1 > 0$ and $v_1 > 0$. If (i) holds, then (B5) is slack and $\epsilon_1 = 0$. But this is impossible. Thus $\alpha_1 > 0$ and $v_1 > 0$. ■

Step 4: The state 3 government liability constraint binds at the optimum.

Proof: $v_3 = 0 \Rightarrow \kappa = p_3 + \epsilon_2 + \gamma_3$. Substituting this into (b7) I get $\alpha_3 B [\cdot] = -\beta$. This equality holds only if $\alpha_3 = \beta = 0$. Clearly, the state 3 participation constraint and the incentive compatibility constraint cannot both be slack at the optimum. Thus $v_3 > 0$. ■

Step 5: (B3) binds at the optimum.

Proof: Suppose $\beta = 0$. Then (b3) and (b7) give $\alpha_3 > 0$. Using this in (B3) yields $g(a_2 - \Delta \theta) > g(a_2)$. This is impossible. Thus $\beta > 0$. ■

Step 6: The state 3 firm liability constraint is slack at the optimum.

Proof: Clearly, $\alpha_3 = \beta = 0$ and $\alpha_3 > 0$, $\beta > 0$ are impossible. Suppose $\alpha_3 > 0$ and $\beta = 0$. Then $T_3 - g(a_3) = T_r > T_r + g(a_2) - g(a_2 - \Delta \theta) > 0 > g(a_2) - g(a_2 - \Delta \theta)$. This is impossible because $\Delta \theta > 0$. I conclude that $\alpha_3 = 0$, $\beta > 0$. ■

Step 7: The state 4 firm and government liability constraints are slack at the optimum.

Proof: (b4) and (b8) tell us that either (i) $\alpha_4 > 0$ and $v_4 > 0$ or (ii) $\alpha_4 = v_4 = 0$. If (i) holds, then (B6) is violated. Thus $\alpha_4 = v_4 = 0$. ■

Step 8: $\tilde{G}_4 > \tilde{G}_1 = \tilde{G}_2 = \tilde{G}_3 = \tilde{G}_r$.

Proof: This follows because $v_1 > 0$, $v_2 > 0$, $v_3 > 0$, and $v_4 = 0$. ■

Step 9: (B5) and (B6) bind at the optimum.

Proof: $\alpha_1 > 0$, $\alpha_2 > 0$, $v_3 > 0$, $v_4 > 0$ tell us that $\epsilon_1 > 0$. (b4) and $v_4 = 0$ tell us that $\epsilon_2 > 0$. ■

Step 10: $T_3 - g(a_3) > T_4 - g(a_4) > T_1 - g(a_1) = T_2 - g(a_2)$. 

Proof: This follows because \( \alpha_4 = 0, \alpha_3 = 0, u_3 > 0, u_4 = 0, \varepsilon_2 > 0. \)

Step 11: (B7) binds at the optimum.

Proof: (B7) binds, i.e., \( \kappa > 0, \because \beta > 0 \) and \( \tilde{G}_2 = \tilde{G}_3. \)

Step 12: For \( i \neq 2, a_i = (g')^{-1}\{p_{i}/(p_i + \gamma_i)\}, \) and \( a_2 = (g')^{-1}\{p_2/(p_2 + \gamma_2) - D\}, \) where \( D = \{p_2/(p_2 + \gamma_2) - g^{-1}(a_2)\}. \)

Proof: From (b5) and (b9) I get \( a_1 = (g')^{-1}\{p_{1}/(p_1 + \gamma_1)\}. \) From (b6) and (b10) I get \( a_2 = (g')^{-1}\{p_2/(p_2 + \gamma_2) - D\}. \) From (b7) and (b11) I get \( a_3 = (g')^{-1}\{p_3/(p_3 + \gamma_3)\}. \) Finally, from (b8) and (b12) I get \( a_4 = (g')^{-1}\{p_4/(p_4 + \gamma_4)\}. \)

Step 13: \( \tilde{A}_2g'(a_2) = \tilde{A}_3g'(a_3) = \tilde{A}_4g'(a_4) > \tilde{A}_2g'(a_2) \), where \( \tilde{A}_i = (p_i + \gamma_i)/p_i, \) \( i = 1, \ldots, 4. \)

Proof: From the proof to Step 12, it follows that \( \tilde{A}_2g'(a_2) < 1 = \tilde{A}_3g'(a_3) = \tilde{A}_4g'(a_4) = \tilde{A}_4g'(a_4). \)

I now check to see that (B4) and (B8) are satisfied. Suppose that \( T_2 - g(a_2) = T_3 - g(a_3 + \Delta \theta). \) This means that \( g(a_3 + \Delta \theta) - g(a_3) = g(a_2) - g(a_2 - \Delta \theta). \) Because \( g' > 0 \) and \( g'' > 0, \) this last equality holds iff \( a_2 > a_3. \) However, a contract which requires that relative to state 3, there be more abatement in the low abatement technology quality state 2, cannot be optimal. Hence \( T_2 - g(a_2) > T_3 - g(a_3 + \Delta \theta). \) Intuitively, we know that for \( i = 2,3, \) either the incentive compatibility constraint binds or the participation constraint binds, but not both. For state 3, the high abatement technology quality state, the incentive compatibility constraint binds; hence, the participation constraint is slack. As contrasted to this, in the low abatement technology quality state 2, the participation constraint binds; hence, the incentive compatibility constraint is slack.

Having shown that (B4) is satisfied, to verify that (B8) is satisfied, it suffices to note that \( \tilde{G}_2 = \tilde{G}_3. \)

This completes the proof of Theorem 1. \( \blacksquare \)