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**DEVELOPING COUNTRIES AND INTERNATIONAL
ENVIRONMENTAL AGREEMENTS: THE CASE
OF PERFECT CORRELATION**

by

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**DEVELOPING COUNTRIES AND INTERNATIONAL ENVIRONMENTAL
AGREEMENTS: THE CASE OF PERFECT CORRELATION**

Amitrajeet A. Batabyal

ABSTRACT

I study the pollution control problem faced by an imperfectly informed supranational governmental authority (SNGA) that wishes to design an international environmental agreement (IEA) for developing countries (DC). The SNGA cannot contract directly with polluting firms in the various DCs; it must deal with such firms through their national governments. Further, owing to national sovereignty, the SNGA is unable to either monitor the actions of DC governments and firms or enforce the terms of the IEA in the event of a contractual breach. In this setting, I study the properties of equitable IEAs in which similar DCs are held to similar environmental standards. In particular, I focus on two cases. In the first case, governments and firms within individual DCs do not collude among themselves, and, in the second case, they do. I show that when the private information of firms and governments across the two DCs is perfectly correlated, whether or not there is collusion, the SNGA can always implement the full information IEA in a Bayes-Nash equilibrium. My analysis tells us that (i) the significance of the monitoring and enforcement problem in such international settings has been exaggerated, and (ii) the technological similarities between DCs have a far greater bearing on the design problem than do the potentially deleterious effects of sovereignty. Indeed, there are a number of situations in which Pareto-efficient IEAs can be designed by the SNGA.

JEL classification: Q25, H77, D82

Key words: international environmental agreement, developing countries, perfect correlation

DEVELOPING COUNTRIES AND INTERNATIONAL ENVIRONMENTAL AGREEMENTS: THE CASE OF PERFECT CORRELATION¹

1. Introduction

With the passage of time, it has increasingly been recognized that environmental protection is a global 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 northern nations 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 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 design effective international environmental agreements (IEAs).² 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 study in this paper.

On the academic front, only very recently have researchers begun to systematically study issues relating to global environmental protection. As a result, many specific questions remain unanswered. What kinds of contracts must a supranational governmental authority (SNGA) design in order to get sovereign nations to voluntarily participate in IEAs in a noncooperative environment?

¹I thank Larry Karp for his input; the usual disclaimer applies. This research has been supported by USDA Cooperative Agreement #1-440310-25241, and by a Faculty Research Grant from Utah State University.

²In this paper I shall use the terms contract and IEA interchangeably.

How is the IEA design question affected by the fact that the SNGA must deal with national governments directly and polluting firms only indirectly? Are there circumstances in which the SNGA can require that pollution be abated at the first-best level? Finally, given that the SNGA is unable to monitor pollution abatement activities in sovereign nations, what steps can it take to mitigate the effects of potential collusion between governments and firms in individual nations?³ These are the specific questions that I shall address 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 the rest of this paper.⁴ In particular, I shall study the interaction of the SNGA with governments and firms in two DCs. The SNGA designs IEAs in which two technologically similar DCs are held to contractually similar environmental standards. This notion of technological similarity is formalized by having: (i) the private information of the two polluting firms, i.e., the random quality component of the abatement technologies; and (ii) the private information of national governments, i.e., the results of monitoring undertaken by the two governments, be perfectly correlated. The reader should not interpret this perfect correlation formalization literally. Given DC demands for the transfer of resources and technology from the developed world, my purpose here is to study the properties of IEAs which are equitable in the sense that they hold similar DCs to similar contractually specified environmental standards. The perfect correlation formalization is an abstraction to this end.

³As we shall see, circumstances will arise in which governments and firms within individual DCs will want to collude to maximize the monetary transfers to be received from the SNGA.

⁴The countries I have in mind are those which would be eligible to receive monetary transfers under the Global Environmental Facility's standard of \$4,000 or less. For more on this, see Rogers (1993, p. 155).

My principal result is that when the private information of firms and governments in the two DCs is very similar, i.e., perfectly correlated, regardless of whether there is collusion between governments and firms in the individual countries, the SNGA can always implement the first-best IEA in a Bayes-Nash equilibrium. I now discuss the connections between my model and some of the related literature concerning IEAs.

2. Environmental Protection, Agency Theory, and the Economics of Hierarchies

Barrett (1994), Black, Levi, and de Meza (1993), Hoel (1992), and Sandler and Sargent (1995) have all studied different aspects of IEAs. Barrett has observed that for IEAs to be successful, they need to be self-enforcing. Black, Levi, and de Meza have determined the minimum number of countries needed to make an IEA viable. Hoel has studied the properties of IEAs, which require that pollutants be abated uniformly. Finally, Sandler and Sargent have shown that the success of IEAs depends on how individual pollution activities add to the total level of pollution experienced by nations. While these papers have certainly advanced our knowledge of some aspects of “. . . the multi-faceted design . . . problem” (Black, Levi, and de Meza, 1993, p. 281), a number of other important questions, which I discussed in section 1, remain unanswered. Consequently, I now discuss my theoretical approach to the IEA design problem.

In the multiagent contract theory literature, Sappington and Demski (1983, hereafter SD) and Demski and Sappington (1984, hereafter DS) have analyzed two-tiered hierarchies with one principal and two agents. DS assume that the private information of the agents, across the two agents, is positively but imperfectly correlated. SD assume that this information is perfectly correlated. SD

show that in an environment with perfect correlation, the principal can always implement the first best contract in dominant strategies. I shall extend the SD analysis by adding a third tier, and then I shall study the properties of the IEAs that the SNGA can implement in a three-tiered hierarchy.

Three-tiered hierarchies with one principal, one intermediary, and one agent have been studied by Tirole (1986, 1988), Kofman and Lawarree (1993), and by Batabyal (1996a, 1996b, 1996c).⁵ In these papers, the focus is on analyzing a hierarchy with a single “fork.” I shall extend this research by adding a second “fork” to the underlying hierarchy. In other words, my task will be to study a two-forked, three-tiered hierarchy. Occupying the top tier of the hierarchy is the relevant international institution or SNGA. This SNGA could be an organization such as the World Bank in its role as an administrator of the Global Environmental Facility (GEF) or the Commission on Sustainable Development (CSD) created in Agenda 21 at the Rio Earth Summit. The second and third tiers of the hierarchy consist of the national government and a representative polluting firm in each of the two DCs.⁶ The rationale for the actual contracting stems from issues including, but not limited to, the harmful effects of nitrogen and/or sulphur emissions. The incidence of pollution may be domestic or transboundary.⁷

The uncertainty in my model stems from the SNGA’s lack of knowledge about the quality of the pollution abatement technology/capability available in each of the two DCs. Whereas the

⁵The Kofman and Lawarree (1993) paper actually has two intermediaries—an external and an internal auditor.

⁶The reader will note that in this modeling scheme, I have conferred on the SNGA the role of principal. As a result, 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 who typically have limited bargaining power in their interactions 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).

⁷See Crane (1993) or Paarlberg (1993) for a discussion of the relevance of international institutions when the incidence of an environmental externality is domestic.

polluting firm in each country always knows the quality of its technology and the government does too in some states of nature, the SNGA is never privy to this information. As indicated previously, the random variable denoting the private information about pollution abatement technology quality is perfectly correlated across the two DCs. From the standpoint of pollution abatement, this means that both countries are technologically very similar. The reader should think of sets of countries, such as Ecuador and Peru, China, and the Philippines, or South Korea and Taiwan, which are technologically very similar. The SNGA's task is to design an incentive compatible, in section 5 collusion-proof as well, IEA, which (i) is equitable in the sense that similar DCs are held to similar environmental standards, and (ii) will lead to optimal pollution abatement. To the best of my knowledge, this problem of designing IEAs for very similar DCs in a hierarchical framework has not been studied before.

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 appearing "green," 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.⁸ Second, the government and the firm in each country receive monetary transfers for their roles in abating pollution. Further, both these players in each DC know that the SNGA cannot monitor their activities owing to sovereignty, or for that matter, enforce the terms of the IEA in the event of a contractual breach. Consequently, there will be circumstances in which there are incentives for the government and the firm to collude to maximize the transfers received from the

⁸See Peterson (1993) for a discussion of some practical instances of possible government/firm collusion in an international setting.

SNGA. Third, as Mookherjee and Png (1995) and others have noted, corruption is an endemic part of public life in many DCs. This suggests a need for explicitly modeling the actions of potentially corruptible agents. Due to these reasons, an important part of this paper will consist of analyzing collusion-proof contracts.

The rest of this paper is organized as follows. In section 3, I describe my model in detail, and then I characterize the properties of the first-best IEA. In section 4, I study the above-described three-tiered hierarchy with no collusion by firms and governments in the two DCs. In section 5, I study the case of collusion by the government and the representative firm in each DC. In section 6, I conclude and offer some suggestions for future research.

3. The Theoretical Framework

3a. Description of the Model

Superscripts A and B will denote the two countries, and subscripts $i = 1, 2, 3, 4$ will refer to the state of nature. In what follows, I shall focus on country A ; the analysis is analogous for country B . The risk-averse polluting firm in A produces clean air, whose output and value are denoted by x^A , $x^A \geq 0$. The polluting firm in A chooses a level of abatement $a^A > 0$, and this firm's cost of abatement is $(a^A)^2/2$.⁹ This firm has a strictly concave and differentiable payoff from abatement function $B\left[T_{ii}^A - \{(a_i^A)^2/2\}\right]$ with $0 < \partial B[\bullet]/\partial T_{ii}^A < \infty$, $\forall T_{ii}^A$. $T_{ii}^A \geq 0$ is the monetary transfer made by the SNGA to the A firm when it produces clean air x_i^A and the B firm produces

⁹The use of this functional form is without loss of generality. All the results of this paper can be obtained by using a general, increasing, and strictly convex abatement cost function.

clean air x_i^B . The A firm's reservation payoff is $B^{AR} = B[T^{AR}]$; B^{AR} and T^{AR} are common knowledge.

The government in A is risk averse. By employing a monitoring device, this government receives a signal s^A from the firm regarding the quality of its abatement technology, and then it (the government) sends a report r^A to the SNGA, indicating what it learned about the quality of this technology/capability. In some states of nature, the government's monitoring device malfunctions, and, hence in these states, the government will be unable to provide the SNGA with an informative report. Upon receiving r^A , the SNGA offers the A government a transfer $G_{ii}^A \geq 0$. The government has a strictly concave and differentiable utility function $V(G_{ii}^A)$, where G_{ii}^A is the monetary transfer made to the A government when it reports r_i^A and the B government reports r_i^B . I assume that $0 < dV(\bullet)/dG_{ii}^A < \infty$, $\forall G_{ii}^A$. The A government's reservation utility is denoted by $V^{AR} = V(G^{AR})$; V^{AR} and G^{AR} are common knowledge. 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 random variable θ^A , which incorporates the uncertainty about pollution abatement technology quality, has binary support $[\theta^{AL}, \theta^{AH}]$, where $0 < \theta^{AL} < \theta^{AH}$. Let $\Delta\theta^A = \theta^{AH} - \theta^{AL}$. Alternately put, the pollution abatement technology can be of low quality, θ^{AL} , or of high quality, θ^{AH} .

The SNGA is risk neutral and it has a welfare function defined over clean air, which takes the form $U = \sum_l (x^l - G^l - T^l)$, where the index l runs over A and B . The quantity of clean air

produced by each firm is $x^l = a^l + \theta^l$, $l = A, B$. As stated, the SNGA's welfare is the difference between total clean air and the sum of government and firm transfers.¹⁰ The SNGA designs the contract, which it offers to the government and to the firm in A . The contract can only be conditioned on what the SNGA actually observes, i.e., the A government's report r^A , the B government's report r^B , the A firm's output of clean air x^A , and the B firm's output of clean air x^B .

There are four states of nature, each occurring with probability $p_i > 0$, where $\sum_i p_i = 1$. The random variables denoting abatement technology quality, θ^A and θ^B , are perfectly correlated. The IEA is *ex ante*, i.e., the SNGA, the government, and the firm in A sign the contract holding symmetric but imperfect information about θ^A . The firm always knows θ^A before choosing abatement. The government, on the other hand, may or may not know θ^A . This depends on whether the government's monitoring device functions or malfunctions. Alternately put, the government's signal s^A may or may not be informative. I can now characterize the four states. They are:

- State 1: $\theta_1^A = \theta_1^{AL}$, $\theta_1^B = \theta_1^{BL}$, $s_1^A = \theta_1^{AL}$, $s_1^B = \theta_1^{BL}$,
- State 2: $\theta_2^A = \theta_2^{AL}$, $\theta_2^B = \theta_2^{BL}$, $s_2^A = 0_2^A$, $s_2^B = 0_2^B$,
- State 3: $\theta_3^A = \theta_3^{AH}$, $\theta_3^B = \theta_3^{BH}$, $s_3^A = 0_3^A$, $s_3^B = 0_3^B$,
- State 4: $\theta_4^A = \theta_4^{AH}$, $\theta_4^B = \theta_4^{BH}$, $s_4^A = \theta_4^{AH}$, $s_4^B = \theta_4^{BH}$.

In state 1, firms and governments in both countries observe that the quality of the abatement technology is low. In this state, the two-government monitoring mechanisms function and hence they provide useful information. In state 2, both firms learn that the abatement technology quality

¹⁰The reader may be wondering about the source of these transfers. One possibility would be to conform to the Rio Earth Summit document known as 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). I have discussed issues related to the SNGA's budget, and contracting with budget balance constraints in Batabyal (1996b).

is low, but the two governments learn nothing. In this state, the two-government monitoring mechanisms malfunction. In state 3, the two firms learn that the abatement technology quality is high and the two governments learn nothing. Once again, the two-government monitoring mechanisms malfunction. Finally in state 4, firms and governments in both countries learn that the abatement technology quality is high. The two-government monitoring mechanisms function effectively in this state.¹¹ I shall assume that $p_1 > p_2$ and that $p_4 > p_3$. In other words, the two monitoring mechanisms are reliable in the sense that they are more likely to function than to fail.

The timing of the game between the SNGA, the A government, and the A firm is as follows. First, the SNGA offers the contract to the government and to the firm in A . Second, the firm learns θ^A and the government receives its signal s^A . Third, the firm chooses abatement α^A . Fourth, clean air x^A is produced by the firm and the government sends its report r^A to the SNGA, indicating what it learned about θ^A . Finally, the SNGA compensates the government and the firm in A by making monetary transfers $G^A(x^A, x^B, r^A, r^B)$ and $T^A(x^A, x^B, r^A, r^B)$.

In the remainder of this paper, I shall assume that the SNGA can verify the veracity of the government report r^A . In other words, if the government signal s^A is noninformative, then the corresponding report r^A reflects this fact and the SNGA can verify that the true facts are indeed as they have been reported. In symbols, $s^A = 0^A \Rightarrow r^A = 0^A$. On the other hand, to keep the SNGA's design problem interesting and to allow for the possibility of government/firm collusion, I shall permit the government to lie and report that its signal is noninformative when in fact such is not the

¹¹I have assumed that the governments always know when their monitoring devices malfunction. More involved formulations in which the governments do not know the states in which their monitoring devices have malfunctioned are possible. These alternate formulations require additional constraints on the SNGA's problem, and they make it very difficult to obtain concrete results.

case.¹² That is, $s^A = \theta^A \Rightarrow r^A \in \{\theta^A, 0^A\}$. This completes the description of my model. I now consider the simplest case in which perfect information is acquired by the SNGA.

3b. The First-Best Optimum

In this case, the SNGA knows the pollution abatement technology quality θ^A and the firm's pollution abatement choice. When this happens, the SNGA bypasses the A government and contracts with the A firm directly. Since the government now has no role to play, it receives its reservation transfer $G^{AR} = V^{-1}(V^{AR})$ in all four states of nature. The SNGA solves

$$\max_{a^A} [a^A + \theta^A - \{(a^A)^2/2\}]. \quad (1a)$$

The first-order necessary condition requires that

$$a_*^A = 1, \forall \theta^A. \quad (1b)$$

We see that in a first-best optimum, the marginal cost of pollution abatement, the LHS of (1b), is set equal to the marginal welfare from abatement. The optimal level of abatement a_*^A equals unity in all four states of nature. The firm receives a transfer for abating pollution, which is independent of the state of nature. This transfer equals $[T^{AR} = B^{-1}(B^{AR}) + 1/2]$, where $1/2$ is the cost of pollution abatement in the first-best optimum. I can now define this first-best optimum.

Definition: In the first-best optimum, (i) the government and the firm in each country are held to their reservation utility and payoff, respectively, (ii) equation (1b) holds, and (iii) the equilibrium contract is Pareto efficient in every state.

¹²The 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 report the wrong state, but in my model, making such a report 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 very 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 maximization problem.

I now discuss the more interesting cases in which the SNGA cannot determine the quality of the abatement technology, or the actual abatement undertaken by the A firm.

4. The No Government/Firm Collusion Case

In this section, I shall disallow the possibility of collusion between the government and the firm in A . When the A government is paid its reservation transfer G^{AR} , it receives its reservation utility V^{AR} , and hence it is fully insured. Furthermore, since I am not allowing for the possibility of government/firm collusion and because the SNGA can verify the government's report by paying G^{AR} , the SNGA can obtain the A government's information at least cost. In terms of the design of the main contract, this means that the three-tiered hierarchy effectively reduces to a two-tiered hierarchy in which the A government plays a completely passive role.

In this setting, the SNGA solves

$$\max_{a_i^A, T_{ii}^A} \sum_{\forall i} p_i (a_i^A + \theta_i^A - T_{ii}^A) \quad (2a)$$

subject to

$$\sum_{\forall i} p_i B \left[T_{ii}^A - \left\{ (a_i^A)^2 / 2 \right\} \right] \geq B^{AR}, \quad (2b)$$

$$p_2 \left[T_{22}^A - \left\{ (a_2^A)^2 / 2 \right\} \right] \geq p_2 \left[T_{32}^A - \left\{ (a_3^A + \Delta\theta^A)^2 / 2 \right\} \right], \quad (2c)$$

and

$$p_3 \left[T_{33}^A - \left\{ (a_3^A)^2 / 2 \right\} \right] \geq p_3 \left[T_{23}^A - \left\{ (a_2^A - \Delta\theta^A)^2 / 2 \right\} \right]. \quad (2d)$$

Constraint (2b) is the firm's participation constraint. Because the contracting is *ex ante*, I have a single probabilistically weighted constraint. The need for this constraint arises from the fact that in this international setting, the SNGA cannot compel the firm to participate in the IEA and abate pollution. Constraints (2c) and (2d) arise because the SNGA has imperfect information about

abatement technology quality θ^A in states 2 and 3. Recall that these are also the states in which the A government's signal s^A is noninformative. Constraint (2c) says that in state 2, if the firm in B abates pollution truthfully, then the firm in A should not abate at level $a_3^A + \Delta\theta^A$ and claim that the state is 3. Similarly, constraint (2d) says that in state 3, given that the B firm is abating truthfully, the A firm should not abate at level $a_2^A - \Delta\theta^A$ and claim that the state is 2. In other words, these two constraints are the Nash incentive compatibility constraints requiring the A firm to behave truthfully, given that the B firm is behaving truthfully. I can now solve the SNGA's problem as stated in (2a)-(2d). I am led to

Theorem 1: The SNGA can implement the first-best IEA in a Bayes-Nash equilibrium. This IEA has the following features: (i) the SNGA obtains the government's information at least cost, (ii) the government's reward equals $G^{AR} = V^{-1}(V^{AR})$ in all states of nature, (iii) only constraint (2b) binds, (iv) the pollution abatement levels satisfy $a_i^A = a_*^A = 1, \forall i$, (v) the transfers to the firm satisfy $T_{11}^A = T_{22}^A = T_{33}^A = T_{44}^A$, (vi) the contract is Pareto efficient in every state, and (vii) the two "out-of-equilibrium" transfers satisfy $T_{23}^A < T_{33}^A + \Delta\theta^A \{(\Delta\theta^A/2) - 1\}$, and $T_{32}^A < T_{22}^A + \Delta\theta^A \{(\Delta\theta^A/2) + 1\}$.

Proof: See the Appendix.

Comparing Theorem 1 with the definition of the first-best optimum in section 3b, it is easy to verify that the contract described in Theorem 1 does indeed implement the first best. Theorem 1 describes the level and pattern of pollution abatement that one may expect to observe in my stylized two-country setting in which the SNGA does not know the quality of the polluting firm's abatement technology, and it must design an optimal IEA, which takes account of the organizational hierarchy. Since the SNGA acquires the government's information in states 1 and 4 and because this

information is verifiable, the firm can be required to abate pollution at the first-best level. The optimal contract then specifies equal monetary rewards to the firm in each of these two states. Hence, $T_{11}^A = T_{44}^A$.

On the other hand, when the state is 2 or 3, the SNGA's information is imperfect. This notwithstanding, Theorem 1 tells us that because: (i) the random variables denoting quality, θ^A and θ^B , in A and B and (ii) the government signals s^A and s^B are perfectly correlated, the SNGA can exploit this fact to require that pollution be abated at the first-best level in states 2 and 3 as well. Consequently, the monetary transfers to the firm are identical in all four states, i.e., $T_{22}^A = T_{33}^A = T_{11}^A = T_{44}^A$.

Intuitively, we can think of the SNGA placing the two polluting firms in a Prisoner's Dilemma game in states 2 and 3. By designing the out-of-equilibrium transfers so that they satisfy the inequalities given in Theorem 1, the SNGA ensures that abating at the "correct" level is the unique Bayes-Nash equilibrium. The results contained in Theorem 1 depend on the perfect correlation of (i) the government signals, and (ii) the random variables denoting abatement technology quality in the two countries. The reader can verify for himself that the first-best IEA can also be implemented by the SNGA in a dominant strategy equilibrium.

At and since the 1992 Rio Earth Summit, there has been considerable discussion about the properties of politically acceptable and economically feasible IEAs. In particular, given DC perspectives on the nature and causes of global environmental degradation, the equity aspect of IEAs has become an important issue.¹³ We have seen that as long as governments and firms in individual DCs do not collude, a SNGA which cares about world pollution can use the technological similarity

¹³For more on this, see Bernauer (1995), Keohane, Haas, and Levy (1993), and Rogers (1993).

of DCs to design an IEA which is equitable and which mimics the first-best IEA. The designed IEA is equitable in the sense that technologically very similar DCs are held to identical pollution abatement standards and the transfers made to the relevant parties in the two countries are also very similar. Moreover, this IEA, described in Theorem 1, mimics the first-best IEA because it satisfies the requirements of the definition of the first-best optimum given in section 3b.

Thus far, we have seen that it is certainly possible to design equitable IEAs; such equitable IEAs hold groups of similar DCs to similar environmental standards. Consequently, such IEAs and the monetary transfers that come with participation in these IEAs should be politically acceptable to DCs. However, given the incentives for government/firm collusion in the individual DCs, there is some question as to the robustness of these equitable IEAs. I now explore this robustness issue by studying the design of collusion-proof IEAs.

5. The Government/Firm Collusion Case

Recall that, because of national sovereignty, the SNGA is unable to monitor the actions of governments and firms in A and B 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 because it must rely on the government's report r^A to design the optimal contract, it is of considerable interest to determine the nature of the optimal IEA that can be implemented by the SNGA when the government and the firm in each of the two countries collude to maximize the total transfers to be received from the SNGA.

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, the firm and the government in each country sign a side contract that entails the offer and acceptance of a bribe from the firm to its government. This side contract is unobservable by the SNGA. The bribe can only be conditioned on what the firm and the government both observe, i.e., the government's report r^A and clean air x^A . With the offer and acceptance of the bribe, the firm's total transfer becomes $\{T^A(\bullet) - b^A(x^A, r^A)\}$ and the government's total transfer becomes $\{G^A(\bullet) + b^A(x^A, r^A)\}$, where $b^A(\bullet, \bullet)$ is the bribe. I shall not concern myself with the question of how the surplus from the bribe is divided. For my purpose, it is only necessary that the bribe be paid by the firm to its government.

Collusion by the firm and the government in each country alters the incentives of the various parties but not, as we shall see, the properties of the optimal IEA designed by the SNGA. To see why the firm in A might want to bribe its government, consider state 4. In this state, the government is indifferent between reporting that it has observed θ^{AH} and reporting that it has observed θ^A . The firm, on the other hand, would prefer that the government report θ^A . This is one instance in which a clear rationale exists for the firm to bribe its government.¹⁴

In order to formulate and solve the SNGA's problem when there is collusion, I shall follow Tirole (1986, 1988) and Batabyal (1996b, 1996c).¹⁵ This method involves the imposition of 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. The reader should note that in this section I am considering simultaneous collusion in both countries. The optimal IEA designed by the SNGA for A is collusion proof on the

¹⁴See footnote 8 as well.

¹⁵For a somewhat different approach to modeling collusion, see Kofman and Lawarree (1993).

assumption that, if the resulting IEAs were not constrained to be collusion proof, government/firm coalitions would form in both DCs. The reader will note that this assumption of “simultaneous collusion” is weaker than the assumption which requires that the contract for A be collusion proof, irrespective of whether there is collusion in B . I can now formulate the SNGA’s problem. The SNGA solves¹⁶

$$\max_{a_i^A, \bar{G}_{ii}^A, \bar{T}_{ii}^A} \sum_{\forall i} p_i \left(a_i^A + \theta_i^A - \bar{G}_{ii}^A - \bar{T}_{ii}^A \right) \quad (3a)$$

subject to (2b), (2c), and (2d) with T_{ii}^A replaced with $\bar{T}_{ii}^A$,

$$\sum_{\forall i} p_i V(\bar{G}_{ii}^A) \geq V^{AR}, \quad (3b)$$

$$p_2 \left[\bar{G}_{22}^A + \bar{T}_{22}^A - \left\{ (a_2^A)^2 / 2 \right\} \right] \geq p_2 \left[\bar{G}_{32}^A + \bar{T}_{32}^A - \left\{ (a_3^A + \Delta\theta)^2 / 2 \right\} \right], \quad (3c)$$

$$p_3 \left[\bar{G}_{33}^A + \bar{T}_{33}^A - \left\{ (a_3^A)^2 / 2 \right\} \right] \geq p_3 \left[\bar{G}_{23}^A + \bar{T}_{23}^A - \left\{ (a_2^A - \Delta\theta)^2 / 2 \right\} \right], \quad (3d)$$

$$p_1 \left[\bar{G}_{11}^A + \bar{T}_{11}^A - \left\{ (a_1^A)^2 / 2 \right\} \right] \geq p_2 \left[\bar{G}_{22}^A + \bar{T}_{22}^A - \left\{ (a_2^A)^2 / 2 \right\} \right], \quad (3e)$$

and

$$p_4 \left[\bar{G}_{44}^A + \bar{T}_{44}^A - \left\{ (a_4^A)^2 / 2 \right\} \right] \geq p_3 \left[\bar{G}_{33}^A + \bar{T}_{33}^A - \left\{ (a_3^A)^2 / 2 \right\} \right]. \quad (3f)$$

Constraint (3b) is the government’s participation constraint. Constraint (3c) tells us that the government should not be able to bribe the firm to lie in state 2 and abate pollution at the level appropriate for state 3. Similarly, constraint (3d) tells us that the government should not be able to bribe the firm to abate pollution in state 3 at the level appropriate for state 2. Constraints (3e) and

¹⁶The collusion-proof transfers are denoted by $\bar{G}_{ii}^A$ and $\bar{T}_{ii}^A$, respectively.

(3f) are the core collusion constraints. The purpose of these two constraints is to make the solution to the SNGA's problem collusion proof. Recall that in states 1 and 4, the government's signal s^A about the firm's abatement technology quality is informative. Thus, in these two states, the government can hide this fact. Given this, constraints (3e) and (3f) tell us that should the firm successfully bribe its government, the total sum of transfers less the cost of pollution abatement in states 1 and 4 cannot be less than the corresponding total in states 2 and 3, respectively. Solving the SNGA's problem (3a) subject to (2b)–(2d) and (3b)–(3f), I can state

Theorem 2: In the three-tiered hierarchy with government/firm collusion, the SNGA can implement the first-best IEA in a Bayes-Nash equilibrium. This contract has the following features:

(i) $a_i^A = a_*^A = 1$, $\forall i$, (ii) the government transfers satisfy $\bar{G}_{11}^A = \bar{G}_{22}^A = \bar{G}_{33}^A = \bar{G}_{44}^A$, (iii) the firm transfers satisfy $\bar{T}_{11}^A = \bar{T}_{22}^A = \bar{T}_{33}^A = \bar{T}_{44}^A$, (iv) only the government and firm participation constraints bind, (v) the optimal IEA is Pareto efficient in all four states, and (vi) the four “out-of-equilibrium” transfers satisfy $\bar{T}_{23}^A < \bar{T}_{33}^A + \Delta\theta^A \{ (\Delta\theta^A/2) - 1 \}$, $\bar{T}_{32}^A < \bar{T}_{22}^A + \Delta\theta^A \{ (\Delta\theta^A/2) + 1 \}$, $\bar{G}_{23}^A < \bar{G}_{33}^A + \bar{T}_{33}^A - \bar{T}_{23}^A + \Delta\theta \{ (\Delta\theta^A/2) - 1 \}$, and $\bar{G}_{32}^A < \bar{G}_{22}^A + \bar{T}_{22}^A - \bar{T}_{32}^A + \Delta\theta^A \{ 1 + (\Delta\theta^A/2) \}$.

Proof: See the Appendix.

To intuitively verify that the IEA described in Theorem 2 is indeed collusion proof, I have to show that constraints (2b)–(2d) and (3b)–(3f) are satisfied. By part (iv) of the theorem, we see that constraints (2b) and (3b) are satisfied. Because $\bar{T}_{23}^A$, $\bar{T}_{32}^A$, $\bar{G}_{23}^A$, and $\bar{G}_{32}^A$ do not enter the SNGA's welfare function or the government and the firm utility and payoff functions, they can be set by the SNGA so as to ensure strict inequality in (2c), (2d), (3c), and (3d). Thus, these four constraints are satisfied. Finally, by parts (i), (ii), and (iii) of the Theorem and the reliability

assumptions $p_1 > p_2$ and $p_4 > p_3$, we see that constraints (3e) and (3f) are satisfied. Thus, this IEA is collusion proof.

To intuitively check that the IEA described in Theorem 2 does indeed implement the first best, recall the definition of the first-best optimum from section 3b. First, note that by part (iv) of the Theorem, the government and the firm are both held to their reservation utility and payoff, respectively. Second, criterion (ii) of the definition is satisfied because part (i) of the IEA requires that pollution be abated at the first-best level in every state of nature. Finally, the fact that the IEA is Pareto efficient in every state follows from condition (v) of the Theorem.

If the SNGA does indeed offer the IEA with the characteristics described in Theorem 2, then its total monetary transfers cannot be altered by changing the government's report or the firm's level of pollution abatement. As a result, the SNGA can be sure that its monetary obligations will be those described in Theorem 2. This is so because the equilibrium IEA is collusion proof. Alternately put, the SNGA designs the best possible IEA from the set of feasible IEA's that are constrained to be collusion proof. Following the intuition of the previous section, the IEA described in Theorem 2 can be thought of as an incentive scheme which effectively places the governments and the firms in the two DCs in Prisoner's Dilemma games. By appropriately designing the "out-of-equilibrium" transfers, the SNGA is able to ensure that misrepresentation of private information does not pay. In other words, truthful pollution abatement and truthful reporting constitute a unique Bayes-Nash equilibrium in the games for the governments and the firms.

Theorem 2 says that like in the no-collusion case studied in the previous section, the SNGA can implement the first-best IEA in a Bayes-Nash equilibrium, even when firms and governments in the two DCs collude to maximize the monetary transfers to be received from the SNGA. This is

a strong result and it has two significant practical implications. First, this result tells us that the concerns of scholars, such as Krasner (1983a, 1983b), who have argued that sovereignty substantially weakens the position of SNGAs and hence the IEAs that such authorities may design, is misplaced.¹⁷ By explicitly modeling the effects of sovereignty, i.e., by disallowing the possibility of monitoring and enforcement and by allowing for the possibility of collusion, I have shown that the SNGA's lack of monitoring and enforcement powers does not preclude it from designing the first-best IEA, i.e., the IEA it would design in the absence of any informational imperfections.

Second, the results of Theorems 1 and 2 greatly strengthen the case for designing IEAs, which have four common structural features. First, these IEAs are individually rational for the DC players, i.e., they satisfy certain participation constraints. Second, these IEAs are incentive compatible because they ensure that misrepresentation of private information by firms and governments is not profitable.¹⁸ Third, these IEAs are collusion proof, i.e., they are immune to the existence of government/firm collusion in the individual DCs. Fourth, these IEAs involve relative performance evaluation. In an IEA with relative performance evaluation, very similar DCs (i) receive similar monetary transfers for participating in an IEA, and (ii) are held to similar pollution abatement standards. As a result, such IEAs are equitable and hence more likely to be acceptable to DCs from a political standpoint.

¹⁷Also see Batabyal (1996a).

¹⁸The reader should note that incentive compatibility is a key feature of the IEA design problem faced by the SNGA. An incentive incompatible IEA would be of little interest because in such an IEA, there would be no conformity between the actions that are desired by the SNGA and the actions that are actually taken by governments and firms in the individual DCs.

6. Conclusions

In this paper I analyzed the question of designing equitable IEAs for technologically similar DCs in an environment in which a SNGA's ability to design contracts is limited by the effects of national sovereignty and by the existence of informational imperfections. In particular, I modeled the institutional setting for the underlying problem as a two-forked, three-tiered hierarchy, and then I studied the nature of optimal *ex ante* IEAs, both without and with collusion. Two general policy conclusions emerge.

First, because the SNGA can implement the first best IEA irrespective of whether there is collusion, in a practical setting, the IEA design question will depend fundamentally on the extent to which an SNGA can exploit similarities in the pollution abatement technologies of the various countries. If two given DCs are very similar technologically so that the pollution abatement technologies of firms are also very similar, then the abatement technology quality parameters, i.e., θ^A and θ^B , are likely to be strongly and positively correlated. In the limiting case of perfect correlation, the SNGA can engage in relative performance evaluation to great effect.

Second, the monitoring and enforcement problem stemming from national sovereignty is not as much of an issue as some scholars would have us believe. As we have seen, the SNGA can get around this aspect of the problem by designing collusion-proof contracts. In this connection, once again, the more important issue concerns the similarities in the quality of the pollution abatement technologies of countries with which the SNGA is attempting to contract.

The analysis of this paper and those of Batabyal (1996b, 1996c) together provide considerable support for the view that IEAs are not inherently doomed due to a basic monitoring and

enforcement problem stemming from national sovereignty. Indeed, as we have seen in this paper, there are a number of situations in which the contractually mandated pattern of pollution abatement is ideal, i.e., first-best.

The line of research pursued in this paper can be extended in a number of different directions. I suggest two possible extensions. First, examining the IEA design problem in a multiperiod setting will enable one to analyze issues such as credibility, commitment, and the possible gains from ongoing relationships. As noted by Parson (1993), our experience with the Montreal Protocol has shown that these are important issues in long-term contracting. Second, the analysis of this paper can be extended by studying alternate institutional scenarios. One possibility would be to analyze a bargaining framework in which DC governments bargain among themselves to decide what the environmental objectives of a SNGA should be. Given the general, albeit uneven, desire for global environmental protection, one may look forward to significant new developments in this area in the future.

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Appendix

In this appendix, I provide the proofs of the two theorems stated in the text of the paper.

Both proofs involve Kuhn-Tucker analysis.

Proof of Theorem 1: T_{23}^A and T_{32}^A do not enter the SNGA's welfare function or the firm's payoff function. Hence, these two transfers can be chosen by the SNGA so that (2c) and (2d) are slack at the optimum. The Lagrangian is $\mathcal{L} = \sum_{\forall i} p_i (x_i^A - T_{ii}^A) + \alpha_1 \left\{ \sum_{\forall i} p_i B \left[T_{ii}^A - \left\{ (a_i^A)^2 / 2 \right\} \right] - B^{AR} \right\}$, where α_1 is the multiplier associated with (2b). Note that for $i = 1, 2, 3, 4$, the Lagrangian depends on a_i^A only through $\left[a_i^A - T_{ii}^A \right]$ and $\left[T_{ii}^A - \left\{ (a_i^A)^2 / 2 \right\} \right]$. Thus $\forall i$, it suffices to maximize $\left[a_i^A - \left\{ (a_i^A)^2 / 2 \right\} \right]$ over a_i^A . This maximization yields $a_i^A = a_*^A = 1$. In other words, the first-best level of pollution abatement results in all four states. The remaining first-order necessary conditions are $\alpha_1 B' \left[T_{ii}^A - (1/2) \right] = 1, \forall i$. This tells us that the participation constraint binds, i.e., $\alpha_1 > 0$, and that $T_{11}^A = T_{22}^A = T_{33}^A = T_{44}^A$. To verify that the optimal contract is Pareto efficient in every state, note that in state 3, as in every other state, $\left\{ \partial B[\bullet] / \partial T_{33}^A \right\} / \left\{ B'[\bullet] a_3^A \right\} = 1$. That is, the marginal payoff from pollution abatement equals the marginal cost of pollution abatement. Finally to obtain the inequalities for the "out-of-equilibrium" transfers, substitute $a_i^A = 1, \forall i$, into (2c) and (2d). This completes the proof of Theorem 1. ♦♦

Proof of Theorem 2: $\bar{G}_{23}^A, \bar{G}_{32}^A, T_{23}^A$, and $\bar{T}_{32}^A$ are not arguments of the SNGA's welfare function, the government's utility function, or the firm's payoff function. Hence, these transfers can be chosen by the SNGA so that (2c), (2d), (3c), and (3d) are slack at the optimum. The Lagrangian is $\mathcal{L} = \sum_{\forall i} p_i (x_i^A - \bar{G}_{ii}^A - \bar{T}_{ii}^A) + \alpha_1 \left\{ \sum_{\forall i} p_i B[\bullet] - B^{AR} \right\} + \alpha_2 \left\{ \sum_{\forall i} p_i V(\bullet) - V^{AR} \right\} + \delta_1 \left[p_1 \left[\bar{G}_{11}^A + \bar{T}_{11}^A - \left\{ (a_1^A)^2 / 2 \right\} \right] - p_2 \left[\bar{G}_{22}^A + \bar{T}_{22}^A - \left\{ (a_2^A)^2 / 2 \right\} \right] \right] + \delta_2 \left[p_4 \left[\bar{G}_{44}^A + \bar{T}_{44}^A - \left\{ (a_4^A)^2 / 2 \right\} \right] - \right.$

$p_3 \left[\bar{G}_{33}^A + \bar{T}_{33}^A - \left\{ (a_3^A)^2 / 2 \right\} \right]$, where $\alpha_i, \delta_i, i = 1, 2$ are the multipliers associated with (2b), (3b), (3e), and (3f), respectively. The twelve first-order necessary conditions are (1) $\{\alpha_1 B'[\bullet] + \delta_1\} a_1^A = 1$, (2) $\{\alpha_1 B'[\bullet] - \delta_1\} a_2^A = 1$, (3) $\{\alpha_1 B'[\bullet] - \delta_2\} a_3^A = 1$, (4) $\{\alpha_1 B'[\bullet] + \delta_2\} a_4^A = 1$, (5) $\alpha_1 B'[\bullet] + \delta_1 = 1$, (6) $\alpha_1 B'[\bullet] - \delta_1 = 1$, (7) $\alpha_1 B'[\bullet] - \delta_2 = 1$, (8) $\alpha_1 B'[\bullet] + \delta_2 = 1$, (9) $\alpha_2 V'(\bullet) + \delta_1 = 1$, (10) $\alpha_2 V'(\bullet) - \delta_1 = 1$, (11) $\alpha_2 V'(\bullet) - \delta_2 = 1$, and (12) $\alpha_2 V'(\bullet) + \delta_2 = 1$.

I shall now proceed by means of six steps.

Step 1: The firm and the government participation constraints bind at the optimum.

Proof: I have to show that $\alpha_i > 0, i = 1, 2$. Suppose $\alpha_1 = 0$. Then (6) tells us that $\delta_1 = -1$, a contradiction. Suppose $\alpha_2 = 0$. Then (11) tells us that $\delta_2 = -1$, a contradiction. Hence, $\alpha_i > 0, i = 1, 2$. ♦

Step 2: $a_*^A = 1 = a_i^A, \forall i$.

Proof: The result follows upon a pairwise comparison of (1) and (5), (2) and (6), (3) and (7) and (4) and (8). ♦

Step 3: $\delta_1 = \delta_2 = 0$.

Proof: Suppose $\delta_1 > 0$. Then (3e) binds. Now (9) and (10) tell us that $\bar{G}_{11}^A > \bar{G}_{22}^A$, and (1) and (2) tell us that $\left\{ \bar{T}_{11}^A - (1/2) \right\} > \left\{ \bar{T}_{22}^A - (1/2) \right\}$. Substituting these values into (3e) and recalling that $p_1 > p_2$, we see that (3e) is slack; this is a contradiction. Thus, $\delta_1 = 0$. A similar line of reasoning using (3), (4), (11), (12), and $p_4 > p_3$, tells us that $\delta_2 = 0$. ♦

Step 4: $\bar{T}_{11}^A = \bar{T}_{22}^A = \bar{T}_{33}^A = \bar{T}_{44}^A$.

Proof: This follows because $\delta_1 = \delta_2 = 0$, and because $a_*^A = 1 = a_i^A, \forall i$.

Step 5: $\bar{G}_{11}^A = \bar{G}_{22}^A = \bar{G}_{33}^A = \bar{G}_{44}^A$.

Proof: This follows from the fact that $\delta_1 = \delta_2 = 0$. ♦

Step 6: The optimal IEA is Pareto efficient in all four states.

Proof: I have to show that the marginal rate of substitution between the transfer and abatement equals unity. I shall use the results of steps 2 and 3. Note that for any state i , $\left\{ \partial B[\bullet] / \partial \bar{T}_{ii}^A \right\} / \left\{ B'[\bullet] a_i^A \right\} = 1$. Hence, the claim follows. ♦

Finally, to obtain the inequalities for the “out-of-equilibrium” transfers, substitute $a_i^A = 1, \forall i$, into (2c), (2d), (3c), and (3d). This completes the proof of Theorem 2. ♦♦