ASSOCIATION for PUBLIC ECONOMIC THEORY

Optimal Provision of Global Public Goods under Uncertainty: Strategic Transfers and Reservations in a Multilateral Treaty Obligation

Jin Kim
KIPF

Seung-jin Shim
Kyungpook National University

Abstract

This paper studies the formation and management of an international entity for promoting the provision of global public goods in a setup of international treaties on concessions and reservations. Based on the convention that there is a discrepancy between the original treaty obligation and the ratified treaty obligation in the multi-lateral treaty implementation, we select the ratification levels of the nations as the choice variables in an economic model. We explicitly analyze the optimal provision of global public goods from the optimal mechanism when the nations face asymmetric information on the ratification levels. Specifically, we characterize the environments where the optimal mechanism with incentive compatibility and participation constraint exists. The result shows that the sophisticatedly calculated transfers in the principal of quid pro quo, and incentive penalties favorably control the international concessions and reservations for the voluntary contributions to producing global public goods.

Submitted: June 16, 2008.

Optimal Provision of Global Public Goods under Uncertainty: Strategic Transfers and Reservations in a Multilateral Treaty Obligation

Jin Kim[a] and Seung-jin Shim[b]

[a] Division of Fiscal Analysis, Korea Institute of Public Finance, Seoul, Korea
Tel: +81-2-2186-2220, e-mail: jkim@kipf.re.kr
[b] The School of Economics and Trade, Kyungpook National University
Tel: +81-53-950-5437, e-mail: shimsj@mail.knu.ac.kr

<Abstract>

This paper studies the formation and management of an international entity for promoting the provision of global public goods in a setup of international treaties on concessions and reservations. Based on the convention that there is a discrepancy between the original treaty obligation and the ratified one in the multi-lateral treaty implementation, we select the ratification levels of the countries as the choice variables in an economic model. We explicitly analyze the optimal reservation levels from the optimal mechanism when the countries face asymmetric information on the ratification levels. Specifically, we characterize the environments where the optimal mechanism with incentive compatibility and participation constraint exists. The result shows that the sophisticatedly calculated transfers in the principal of quid pro quo control the international concessions and reservations.

Key Words: Global Public Goods, Concessions, Reservations, Transfers, Multi-lateral Treaty

JEL Code: H87, K33, F53, C72

1. Introduction

The importance of global public goods (GPGs) has recently grown in various fields such as environments, diseases, and financial crises. In particular, the demand for GPGs has increased apace with globalization.[1] We have also recognized that net benefits from GPGs are large. As Sandler (1997) points out, in the extreme case of GPGs, the good's benefits disperse worldwide; for instance, efforts to curb global warming, to reduce ozone depleting chlorofluorocarbon (CFC) emissions, to map the human genome, or to preserve the earth's biodiversity. However, GPGs always have the characteristics of free rider problems and underproduction.

International cooperative arrangement to supplying GPGs is normally codified in international treaties, as Barrett (2001) presents. It used to be conventional that, to promote the stability of international treaties, the involved countries are not allowed to consider voluntary reservations or side payments. However, there has been a dramatic change in the international conventions on the introduction of side payments and voluntary reservations. It is not a new phenomenon that the countries involved would like to think of side payments or transfers such as in the international environmental

[1] See Sandler (1997), Kaul, Grunderg and Stern (1999), and Ferroni and Mody (2002).

agreements,[2] or voluntary reservations such as in the 1969 Vienna Convention.[3]

This paper investigates international treaties on the provision of GPGs such as international environment agreements within the viewpoint of concessions, reservations, and transfers formally in the framework of mechanism design. The focal point of this exercise is on informational incompleteness, under which we model the situation where countries would like to set up an optimal mechanism when there is informational asymmetry among them. Thus, we model the situation where countries may do strategic actions in the given games consisting of the mechanism and any realized state.

For this purpose, we will consider two stages in a strategic sense; the first stage for concessions and the second for ratification/reservations.[4] At the stage of concessions, countries meet and form a treaty for the amount of GPGs and each country's contribution limit. At the stage of reservations or ratifications, each country ratifies the level of concessions with reservation modifications.

Based on the convention that there is a discrepancy between the original treaty obligation and the ratified one in the multi-lateral treaty implementation, we select the

[2] Barrett (2001) studies the feature of side payments in the international environmental agreements.

[3] Refer to Fon and Parisi (2003) for reservations.

[4] Fon and Parisi (2003) analyze the characterization of the Vienna Convention in the viewpoint of law economics. They introduce an economic model to analyze the mechanism of concessions and reservations in the history of international treaties.

ratification levels of the countries as the choice variables in an economic model. We explicitly analyze the optimal reservation levels of the optimal mechanism when countries face asymmetric information on the ratification levels. Specifically, we characterize the environments where the optimal mechanism with incentive compatibility and participation constraint exists.

Specifically, by using the expenditure minimization behavior,[5] we can formalize indirect utility functions as valuation functions, to which we add mechanisms with message spaces and the rules of reallocation and monetary transfer decisions. Based on the mechanism design theory of the Groves mechanisms, we analyze the possibility of incentive mechanisms with transfers in the case of preference uncertainty. We finally characterize a necessary and sufficient condition for the existence of the mechanism.[6]

This paper consists of 4 sections. The second section introduces our basic model of incomplete information. Section 3 lays out the contents of the literature of the Groves mechanisms, and supplies a proposition. Section 4 discusses the meaning of the proposition in our context.

[5] See Ihori (1994, 1996) for its development in the context of international public goods.
[6] Laffont and Martimort (2005) recently analyze the design of incentive mechanisms for the provision of transnational public goods under asymmetric information among countries.

2. Model

2.1. *Expected benefit from GPGs and its sharing over countries*

From a practical point of view, there would be four cases on the basis of expected benefit from GPGs and benefit sharing among countries, as in <Table 1>.

In the case A of <Table 1>, the expected benefit from GPGs is large and fairly shared among countries, which take part in providing GPGs. In this case, there is no problem in discussing and providing GPGs. In the cases B and D, GPGs are not worth to be discussed, because small and even minus benefit from GPGs is expected. In the case C, it generally takes place in the real international economic society, in particular, between the developed and developing country. As the large benefit is expected from GPGs, it is desirable that countries take a cooperate action for providing GPGs. Nevertheless, there are some cases where countries are not willing to cooperate actively, especially in the case where not all the countries participating in negotiation for providing GPGs can get the impartial distribution of the expected net benefit from GPGs.[7]

The case of C_1 in <Table 1> represents that every country gets net benefits from GPGs. However, there is a difference in net benefit from GPGs among countries. Some

[7] See Barrett (2001).

countries gain much from GPGs and others not. The country that is not much benefited is passive on taking part in the international treaty on GPGs. In the case of C_2, some countries gain much from GPGs and others look to GPGs for minus net benefits. The country that gets the minus net benefits will react adversely to taking part in the international treaty on GPGs.

<Table 1> Net benefit from GPGs and its sharing over countries

<table>
<tr><td colspan="2" rowspan="2"></td><td colspan="2">Net benefit (NB) from GPGs</td></tr>
<tr><td>Large</td><td>Small/minus</td></tr>
<tr><td rowspan="2">Benefit Sharing</td><td>Fair</td><td>Case A</td><td>Case B</td></tr>
<tr><td>Unfair</td><td>Case C

C_1: NBi>.....>NBj>0, $GNB_{c_1} = \sum_{i=1}^{n} NB_i > 0$
Country j is passive on the international treaty for provision of GPGs

C_2: NBi>...>0>...>NBj, $GNB_{c_2} = \sum_{i=1}^{n} NB_i > 0$
Country j is negative on the international treaty for provision of GPGs:</td><td>Case D</td></tr>
</table>

Even in the cases C_1 and C_2, if fairness would be improved via a cooperative installation of the optimal mechanism, there will be an optimal provision of GPGs. For

this, the incentive mechanism with (monetary) transfers in the case of preference differences in GPGs is about to be considered.

2.2. *Basic model*

We assume that n countries are interested in forming a treaty on GPGs. There are two goods; a global public good G and a private good c. We restrict our attention to quasi-linear utility functions; $u^i(c_i, G) = c_i + \theta_i \ln(G)$ for country i where θ_i is the degree for preferring G with respect to c. And G consists of each country i's contribution g_i, which is transformed from the private good c_i; $G = g_1 + g_2 + \ldots + g_n$. By assuming that c_i is a numeraire, country i's budget constraint would be $c_i + p\, g_i = Y_i$, where p denotes the unit cost for producing g_i, and Y_i income, respectively.

We assume that p and Y_i's are given fixed and public information, and that θ_i's are private information called types. Let $\Theta_i = [\underline{\theta}, \bar{\theta}]$ be the common set of types with $\underline{\theta} > 0$. Let us decompose the state set $\Theta = \prod_i \Theta_i$ into n subsets; for each i, $\Theta_i^* = \{\theta \in \Theta \mid \theta_i = \max_j \theta_j\}$ is the set of the states where country i has the highest preference parameter.

(1) *The stage of a treaty on concessions*

We consider two stages in a strategic sense; the first stage for concessions and the second for reservations. At the stage of concessions, countries meet and form a treaty for the amount of G and each nation's contribution limit. At the stage of reservations, each country ratifies the level of concession with reservation modification.

At the stage of a treaty on concessions, the countries would like to join a treaty on providing GPGs. However, the types of countries are not realized at this moment. The important thing to be done by the countries at this stage, then, is how to take a kind of risk about the degree of preferring G to c. By assuming that the countries take the very conservative stance for uncertainty, an international treaty would be formalized at the case $\overline{\theta}$ of the highest degree of preferences. Then the Pareto optimal allocation at $\overline{\theta}$ is that for each i, $\overline{g}_i = \frac{\overline{\theta}}{p}$ and $\overline{c}_i = Y_i - \overline{\theta}$, thus $\overline{G} = \frac{n}{p}\overline{\theta}$. We here assume that the level of concessions in an international treaty is determined by $\overline{g}_i(\theta) = \frac{\overline{\theta}}{p}$ for any θ. Of course, the countries know that that level is functioned as the maximal level of concessions and that they will later have a chance to have reservations from that level.

At the stage of concessions, the types of countries are realized and the mechanism based on the international treaty is operated. The information on the types is revealed at this moment. However, the information on the preferences is private, thus there may be asymmetry in information. It is well known that there is a free rider problem in this

setup. There is an incentive to understate the importance of the GPG in order to reduce the contribution for the GPG because of externality and asymmetric information. Since each country i knows her preference parameter θ_i and is only aware of the distribution of the other country's preference parameters, one of the important roles of the international entity would be how to obtain the true information about θ_i's from the member countries.

In order to implement the first-best allocation, we use the Groves mechanism in the optimal international entity. Thus, we assume that countries can install the international entity of an international agency that collects the reports on types from the member countries and decides allocations and transfers for the member countries.

(2) *The stage of ratification; reservation mechanisms*

The optimal level of ratification through the legal process in each country would be calculated if there were complete information on the preference parameter θ. In a sense, the optimal level would be obtained as a byproduct from the Pareto optimal allocation in our model. The Pareto allocation is that, for each i at θ, $g_i(\theta)=\frac{\theta_i}{p}$ and $c_i(\theta) = Y_i - \theta_i$, thus $G(\theta)=\frac{1}{p}\sum_i \theta_i$. Let A be the set of all the feasible outcomes with $(c_1, \ldots, c_n, g_1, \ldots, g_n) \in A$. Then, by using indirect utility functions from the above-

mentioned method, we may set up a valuation function $v_i(\cdot, \theta_i)$ over A for each type θ_i. Specifically, the payoff of country i with type θ_i from the reports $\hat{\theta}$ is

$$v_i((c(\hat{\theta}), g(\hat{\theta})), \theta_i) = \theta_i \ln(\frac{1}{p}\sum_k \hat{\theta}_k) + Y_i - \hat{\theta}_i . \quad (1)$$

We can verify that the valuation functions in (1) satisfy the convexity condition of Holmström (1979). Thus, by following Makowski and Mezzetti (1994), we can apply the Groves mechanism into our setup.

Before the formal analysis of the Groves mechanism in Section 3, we now explain why we focus on the Groves mechanism.

We will develop the conservative concessions at the first stage with the possibility of reservations at the second stage. To do this purpose, we can think several alternative mechanisms such as (i) the status quo without a certain mechanism, (ii) a Nash equilibrium without transfers, (iii) an optimal reservation mechanism with transfers. "No mechanism" in (i) means that there is no explicit and intentional concern on a central entity in the level of international society. Then the concessions given already are to be just an empty promise without any commitment.

Nash equilibrium without transfers in (ii) is a la Ihori (1994, 1996). Even though there is an improvement on the level of international treaty, that level is below the optimal level.

Optimal reservation mechanism with transfers in (iii) would be constructed a la Groves and Loeb (1975). The international level of ratification is optimal and there are monetary transfers among countries. Section 3 will show the formal analysis of the mechanism design in the context of international treaties.

3. Incentive mechanism design under uncertainty of θ_i

A direct mechanism[8] is denoted by (Θ,<s, t>). Θ is the message space of the type reports. <s, t> is an outcome function which consists of a decision rule s : $\Theta \rightarrow$A and a transfer scheme t=($t_1,...,t_n$) with $t_i : \Theta \rightarrow \mathbb{R}$. Given <s,t>, country i's payoff with type θ_i from a report $\hat{\theta}$ is $v_i(s(\hat{\theta}), \theta_i) + t_i(\hat{\theta})$. We will use the notation <s,t> for a direct mechanism.

The global gain function from the Pareto allocation is

$$g(\theta) \equiv \sum_i v_i((c(\theta), g(\theta)), \theta_i) \equiv [\sum_i \theta_i \ln(\frac{1}{p}\sum_k \theta_k) + \sum_i Y_i - \sum_i \theta_i]. \quad (2)$$

As a direct mechanism is installed and a state is realized, countries face a direct revelation game. A mechanism <s,t> is dominant-strategy incentive compatible if every country has the incentive to report her own type honestly regardless of the others' report schemes at any state, i.e., for all i, for all θ_{-i}, for all θ_i, and for all θ'_i,

[8] See Dasgupta, Hammond, and Maskin (1979).

$$v_i(s(\theta_{-i},\theta_i),\theta_i) + t_i(\theta_{-i},\theta_i) \geq v_i(s(\theta_{-i},\theta'_i),\theta_i) + t_i(\theta_{-i},\theta'_i). \quad (3)$$

A decision rule s is outcome-efficient if $\sum_i v_i(s(\theta),\theta_i) = g(\theta)$ for all θ, that is, if it always realizes the global gain. A mechanism <s,t> is a first-best dominant-strategy mechanism if it is outcome-efficient and dominant-strategy incentive compatible.

Since our setup satisfies the convexity condition in Holmström (1979), we can use his result that a mechanism is a first-best dominant-strategy if and only if it is a Groves mechanism. Following Makowski and Mezzetti (1994), we can define the participation charge on country i at state θ as the difference of i's payoff from the global gain; $h_i(\theta) \equiv g(\theta) - v_i(s(\theta),\theta_i) - t_i(\theta)$ for all i and θ. A mechanism <s,t> is a Groves mechanism if it is outcome-efficient and its participation charges on country i are independent of i's type for each i. Then, country i's payoff from the participation in a Groves mechanism at state θ is

$$v_i(s(\theta),\theta_i) + t_i(\theta) = g(\theta) - h_i(\theta_{-i}) \quad (4)$$

Since each country's participation charges are non-distortionary lump-sum in Groves mechanisms, there is no incentive for any country to lie in the direct revelation game. One simple Groves mechanism is a mechanism with zero participation charges; $h_i(\theta) = 0$ for all i and for all θ. Then each country's payoff would be equal to the global gain $g(\theta)$ at each θ, and by using (4) we know that the zero-charge Groves

mechanism incurs a deficit $g(\theta) - v_i(s(\theta), \theta_i)$ for country i at state θ. The (*ex ante*) expected budget deficit for country i in the zero-charge Groves mechanism is

$$B_i \equiv E[g(\theta) - v_i(s(\theta), \theta_i)] = E[\sum_{j \neq i} \theta_j \ln(\frac{1}{p} \sum_k \theta_k) + \sum_{j \neq i} (Y_j - \theta_j)]. \quad (5)$$

A mechanism <s,t> is *ex post* individual rational (EPIR) if its payoff is not negative for any country at any state. [9]

Since the international entity does not observe country i's type, the maximal amount that the international entity can charge on country i without violating country i's EPIR condition is, by using (4), $c_i(\theta_{-i}) = \min_{\theta_i} \{g(\theta)\}$ for all θ_{-i}. Then, the (*ex ante*) expected lump-sum charge without violating country i's EPIR condition is

$$C_i \equiv E[c_i(\theta_{-i})] = E[\sum_j \theta_j \ln(\frac{1}{p}(\sum_{j \neq i} \theta_j + \underline{\theta})) + \sum_j Y_j - \sum_{j \neq i} \theta_j - \underline{\theta}]. \quad (6)$$

(5) and (6) might be interpreted as two edges of a `benefit-charge' analysis, in that for each country the international entity measures the benefit from the zero-charge Groves mechanism and levies the corresponding lump-sum charge for it.

In plain terms, an annoying problem in the Groves mechanism literature is how to fairly divide the expected surplus from the mechanism when $\sum_i C_i \geq \sum_i B_i$. We introduce two surplus-division methods; equal division and proportional division. The former is related with *ex ante* budget balancedness (EABB), $E[\sum_i^n t_i(\theta)] = 0$. The latter

[9] We assume that the outside option payoff of any country i at any state is zero.

is related with zero expected net transfer (ZENT), E[$t_i(\theta)$]=0 for each i.

Makowski and Mezzetti (1994) obtain a necessary and sufficient condition for the existence of the efficient dominant-strategy mechanism with EPIR and EABB; $\sum_i C_i \geq \sum_i B_i$. Now, we propose a necessary and sufficient condition for the existence of an efficient dominant-strategy mechanism with EPIR and ZENT.

Proposition 1: There exists an international entity which is first-best dominant-strategy incentive compatible, ex post individual rational (EPIR), and zero-expected net-transferred (ZENT) iff $E[c_i(\theta_{-i})] \geq E[g(\theta) - v_i(s(\theta), \theta_i)]$ for all i.

Proof: (If) Define a transfer scheme t by $t_i(\theta)=g(\theta)- v_i(s(\theta), \theta_i) - c_i(\theta_{-i}) + K_i$ for all i and θ, where $K_i = E[c_i(\theta_{-i})] - E[g(\theta) - v_i(s(\theta), \theta_i)] \geq 0$. Then, <s, t> is a Groves mechanism. It's trivial to check out EPIR and ZENT.

(Only if) By the result of Makowski and Mezzetti (1994), it suffices to show that E[$t_i(\theta)$]=0 for all i. By definition, $E[t_i(\theta_i)] = 0$ for all i. Q.E.D.

4. Implications

4.1. *The existence of optimal mechanisms*

The above conditions in Proposition 1 bring forth the range of the consumption level of non-GPG for the existence of the incentive mechanism in the two-country case; for EABB with (7) and for ZENT with (8), respectively.

$$\bar{c}_1 + \bar{c}_2 \geq N \equiv E[\ln[(\frac{\theta_1 + \theta_2}{(\theta_1 + \underline{\theta})(\theta_2 + \underline{\theta})})^{\theta_1+\theta_2}]], \tag{7}$$

$$\bar{c}_i \geq N_i \equiv E[\ln[\frac{(\theta_1 + \theta_2)^{\theta_j}}{(\theta_j + \underline{\theta})^{\theta_1+\theta_2}}]], \text{ where i, j=1, 2 and } i \neq j. \tag{8}$$

with $\bar{c}_i \equiv Y_i - \underline{\theta}$ being the maximum consumption level of non-IPG of country i

<<Fig 1> here>

Not only the global consumption level is important, but also each country's consumption level must be large enough to match the condition for the existence of the international entity. On the other hand, the critical values representing the range of consumption levels are determined by the parameters of utility functions. Under preference uncertainty, the absolute level of private consumption is an important criterion for establishing an efficient international entity with incentive compatibility and individual rationality.

4.2. Optimal/Universal reservation level

The merit of our model is that we could explain the co-existence of concessions and reservations in reality in the meaningful way. There is an alternative way to explain

concessions and/or reservations. That is to calculate, at one time, the optimal level of concessions in the framework of mechanism design. However, it is highly likely that there is usually the mixture of concessions and reservation in reality.

Our interpretation of the reservations in international treaties has two concepts. On the one hand, related with Fon and Parisi (2003), there is an intra-country reservation, which is the level of openness to the international concessions. Our result would be directly concerned with this intra-country level of reservation in the model of a continuum of concession levels. On the other, related with Barrett (2001), we may think of an inter-country reservation, which is a kind of "take it or leave" decision for each country. We could discuss a way of thinking our analysis to this inter-country reservation in the framework of two groups of countries with different income levels.

(1) *Optimal reservation level: Intra-country reservations*

The reservation level at the stage of ratification is defined as

$$r_i(\theta) = \bar{g}_i(\theta) - g_i(\theta) = \frac{1}{p}(\bar{\theta} - \theta_i) \qquad (9)$$

where the first term, $\bar{g}_i(\theta)$, is given by the commitment of concessions and the second, $g_i(\theta)$, is the optimal level of concessions evaluated by the analysis.

The first term is the concession level in the treaty at the stage of concessions. It is

just agreed at the most conservative stance. The second term is the final level of concessions in the treaty at the stage of ratification. It is agreed at the optimal level. The difference $r_i(\theta)$ is the optimal reservation level, which would be observed in reality with variations from uncertain noisiness.

The important question in Fon and Parisi (2003) is that how to establish an incentive compatible mechanism to obtain the optimal level of reservations in the context of the mechanism design. Compared with Fon and Parisi (2003) with discrete types, we consider continuous types. Our analysis permits many countries more than two in Fon and Parisi (2003).

(2) *The universal reservation: Inter-country reservations*

The critical question in Barrett(2001) is that how does the introduction of side payments in the Montreal Protocol make it possible to establish a universal reservation and to promote to the formation of a universal agreement on a treaty. By using our analysis with a minor addition, we can discuss the meaning of Barrett(2001)'s conclusion.

We assume that there are l countries with the equation (8) being satisfied, m countries with the equation (7) not being satisfied but the equation (8) being satisfied.

Then, (i) it is possible that the former l countries could form a treaty on concessions without the latter m countries' participation. However, (ii) it is also possible that all the countries make a treaty on concessions with a possible later reservation.

There are several reasons for preferring the latter method. Firstly, the universal concessions with all the countries make it easy to introduce more concessions and reservations with transfers than a treaty of concessions with a small number of countries. Sunk in the treaty, the rich countries would listen to and meet the poor countries, and become more generous to the problems of the poor. Secondly, there would be an additional possibility of treaty in the sense of budget balance in the international entity. The universal treaty may promote the conventions and meetings among its member countries so as to increase the probability of the mechanisms with ex ante budget balanceness in (7) even when there is no possibility of the mechanisms with zero expected net transfer in (8).

References

Barrett, S. (2001), International cooperation for sale, *European Economic Review* 45: 1835-1850

Dasgupta, P.S., P.J. Hammond, and E.S. Maskin (1979), The implementation of social choice rules: Some general results on incentive compatibility, *Review of Economic Studies* 46: 185-216

Ferroni M. and A. Mody (2002), *International Public Goods; Incentives, Measurement, and Financing*, The World Bank

Fon V. and F. Parisi (2003), The Hidden bias of the Vienna Convention on the law of treaties, Law and Economics Working Paper Series 03-20, George Mason University

Groves, T. and M. Loeb (1975), Incentives and public inputs, *Journal of Public Economics* 4: 211-226

Holmström, B. (1979), Groves schemes on restricted domains, *Econometrica* 47: 1137-1144

Ihori, T. (1994), Strategic transfers and private provision of public goods, *Journal of Public Economics* 57: 489-505

Ihori, T. (1996), International public goods and contribution productivity differentials, *Journal of Public Economics* 61: 139-154

Kaul, I., I. Grunberg, and M. Stern (1999), *Global Public Goods: International Cooperation in the 21st Century*. New York and Oxford: Oxford University Press

Laffont J.J. and D. Martimort (2005), The design of transnational public good mechanisms for developing countries, *Journal of Public Economics* 89: 159-196

Makowski, L. and C. Mezzetti (1994), Bayesian and weakly robust first best mechanisms: Characterizations, *Journal of Economic Theory* 64: 500-519

Sandler, T. (1997), *Global Challenges: An Approach to Environment, Political, and Economic Problems*, Cambridge, U.K.: Cambridge University Press

<Fig. 1>