Can heterogenous countries form homogenous International Environmental Agreements?[1]

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January 2007
preliminary version

[1]We want to thank the German Research Foundation (DFG) for financial support through the SPP 1142 program on "Institutional Design of Federal Systems".

Abstract

JEL classification: C7, D62, H77

Keywords: International Environmental Agreements, coalition formation, heterogenous countries

Standard literature analyzes the stability of International Environmental Agreements (IEAs) for homogenous countries. We reconsider this problem for heterogeneous countries which differ in their marginal abatement costs. This enables us to study the coalition structure. Intuitively speaking, countries with high costs feel a stronger incentive to join an IEA than their low costs counterparts. Low cost countries form pure stable coalitions, while the opposite holds for the high cost counterparts. Mixed coalitions require that at least all low cost countries are members.

1 Motivation

Supranational institutions have often not the political means to restrict global environmental problems. In this case, only voluntary cooperations between countries can reduce environmental damages significantly. The standard literature analyzes the stability of International Environmental Agreements (IEAs) for homogenous countries, where the analysis focuses mainly on the size of stable coalitions. We reconsider this problem for heterogenous countries.[1] To keep the analysis simple, we assume that the countries' costs for abatements can be of two types, either high or low. Following the literature on IEA, we apply the standard approach to study coalition formation formulated by Barrett (1992, 1994) and Carraro and Siniscalco (1993). Countries face a two-stage game where they decide at the first stage whether to sign an IEA or not. Subsequently, in the abatement game signatories and outsiders decide on their policy measures. As countries are heterogenous, we can focus on the question which type of countries join an IEA?

The paper is organized as follows: In section two we present the economic framework which is followed by the analysis of the abatement game. Subsequently, in section 4 we analyze the formation of an IEA. Finally, we present some concluding remarks.

2 Economic Framework

Consider a complete information game on coalition formation. Analogous to the standard literature of forming an IEA, all countries are assumed to have a payoff which consists of the difference between benefit of environmental quality and countries' abatement costs. They are a priori symmetric except for their cost structure. To simplify the analysis we distinguish two types only: Countries have either relatively low or high marginal abatement costs. These costs are c or $C = cd$, with $d > 1$, where the parameter d indicates the extent of the heterogeneity in countries' marginal costs.

A low and high cost country's payoff (p, P) is given as the difference between quadratic benefit and linear abatement costs

$$p = \mathcal{A}[1 - .5\mathcal{A}] - ac \quad \text{and} \quad P = \mathcal{A}[1 - .5\mathcal{A}] - AC, \tag{1}$$

[1] McGinty (2007) presents a first attempt to deal with heterogenous countries. However, the resulting IEA can only be stabilized by side payments, i.e. the surplus of a coalition is split evenly among the signatories. In that case the incentives to form an IEA are somehow different to those in the present paper.

where $\mathcal{A}$ corresponds to aggregate abatements of all countries, while $(a, A) \geq 0$ is the individual measure financed by the low and high cost country.

Furthermore, there we have (n, N) countries of type (c, C). According to the literature, cf. Barrett (1992, 1994) and Carraro and Siniscalco (1993), we model a two-stage game, where the countries decide at the first stage whether or not to sign a single International Environmental Agreement (IEA).[2] A non-trivial coalition consists of at least $s + S \geq 2$ members, where (s, S) corresponds to the number of signatories of type (c, C). Consequently, $(N - S) + (n - s)$ countries remain outside the IEA. To solve the coalition formation game, countries must anticipate the equilibrium at the second stage (the abatement game). Thus, the game is solved through backward induction.

3 Second Stage: The Abatement Game

In the abatement game each outsider determines its abatement level individually. Within the coalition the IEA members agree on a mandatory abatement level for all signatories. All countries (signatories and singletons) determine their abatements simultaneously: outsiders with marginal abatement (c, C) fix their measures $(a, A) \geq 0$ non-cooperatively against all other countries, while each signatory finances $M > 0$ abatements (in equilibrium). Obviously, all signatories $(s + S)$ behave mutually cooperative and non-cooperative against the outsiders.[3]

At the second stage, we end up with two outsider groups and the members of an IEA. First, we study what the coalition does. They adopt a measure by maximizing the aggregate payoff, or equivalently a representative payoff where marginal cost are at an average level $[(sc + SC)/(s + S)]$. This mandatory abatement level can be interpreted as the compromise the IEA members agree on. According to equation (1) a signatories' payoff is (p^s, P^s), while outsiders' payoffs are (p^o, P^o) for type (c, C). The first-order condition of the IEA representative is

$$(s + S)\left[1 - \mathcal{A}\right] - \frac{s + dS}{s + S}c = 0. \tag{2}$$

[2]Contrary to Barrett (1992, 1994) we simplify the strategic interaction between the IEA signatories and the countries outside as we abstract from a Stackelberg behavior of the IEA members. We focus on simultaneously acting countries like in Carraro and Siniscalco (1993). However, as we stick to a model where all outsider countries do not engage in environmental concerns, both types of modelling show almost identical results.

[3]The existence of the Nash equilibrium at the second stage is guaranteed as the payoff is strictly concave in its own and continuous in the opponents' strategy. Furthermore, according to Finus et al. (2005) the abatement equilibrium is unique.

The aggregate abatements $\mathcal{A}$ consists of the sum of the abatements of the signatories $(s+S)\,M$, and the total amount of outsiders' abatements $(n-s)\,a+(N-S)\,A$.

The outsiders' payoffs are (p^o, P^o) for countries of type (c, C) and their necessary first-order conditions are

$$\frac{\partial p^o}{\partial a} = 1 - \mathcal{A} - c \leq 0 \quad \text{and} \quad \frac{\partial P^o}{\partial A} = 1 - \mathcal{A} - cd \leq 0. \tag{3}$$

As the coalition internalizes partly the environmental spillover among the IEA members, the first-order conditions of insiders and outsiders differ in their marginal benefits by the coalition size $(s+S)$. As a first consequence, we can state that both types of outsider countries become complete free-rider in equilibrium for a non-trivial coalition $(s+S) \geq 2$, i.e.

$$a^* = A^* = 0 \quad \text{and} \quad M^* = \frac{1}{s+S} - \frac{(s+dS)c}{(s+S)^3}. \tag{4}$$

As usual for a coalition $(s+dS)/(s+S)^2 < 1$, each outsider becomes a complete free-rider. Thus, in equilibrium only the signatories are active, $M^* > 0$. Individual abatements M^* as well as the aggregate $\mathcal{A}^* = (s+S)M^*$ are increasing in average marginal abatement costs of the IEA members. Obviously, the aggregate $\mathcal{A}^*$ increases with the coalition size.

4 First Stage: Coalition formation

The aim of the paper is to analyze the coalition formation for heterogenous countries. We focus on the question, whether both types of countries are actively engaged in an IEA? This analysis depends on the payoffs at the first stage and the equilibrium of the abatement game at stage two. Distinguishing the types, the relevant payoffs are $p^{o^*}, P^{o^*}, p^{s^*}$ and P^{s^*}, respectively for each type there an insider and an outsider payoff. The payoffs for type C are similar to that for c which are given by

$$p^{o^*} = \mathcal{A}^* - .5\mathcal{A}^{*\,2}, \quad \text{and} \quad p^{s^*} = \mathcal{A}^* - .5\mathcal{A}^{*\,2} - M\ c. \tag{5}$$

For a stable coalition, we need to look at internal and external stability for both types of countries. External stability requires that no outsider has an incentive to join the coalition, while internal stability guarantees that no insider wants to leave the IEA. The external and internal stability condition for type c corresponds to $p^{s^*}(s+1, S) \leq p^{o^*}(s, S)$ and $p^{s^*}(s, S) \geq p^{o^*}(s-1, S)$. Similar conditions hold for countries with high marginal costs. This definition is conform with that of cartel stability, first presented in the oligopoly literature by d'Aspremont and Gabszwicz (1986).

4.1 Non-Existence of High Cost Coalitions

As we are interested in the type of countries that form a stable IEA, we first analyze whether high cost countries can build a coalition without a low cost country joining the IEA. Intuitively speaking, a coalition with $s = 0$ and $S \geq 2$ seems to be relatively not very promising as such an IEA does not integrate countries with low cost potential. At least these low cost countries have an incentive to join the IEA such that a pure high cost coalition becomes unstable.

Proposition 1 *Coalitions without a low cost country are unstable.*

Proof: Contrary to the conjecture of the proposition, let us assume that there does exist a stable pure high cost coalition with $(s^* = 0; S^* \geq 2)$. In that case, both stability conditions for high cost countries hold, while the IEA is externally stable for low cost countries $s^* = 0$. Analyzing the stability for high and low cost countries we can show that $(s^* = 0, S^* \geq 2)$ can not be stable for $d > 1$: Internal stability for high cost countries requires $P^s(s,S) \geq P^o(s,S-1)$. Furthermore, low cost countries do not intend to sign the IEA if $p^s(s,S) \leq p^o(s-1,S)$ for all $1 \leq s \leq n$. These two conditions can be rearranged as follows:

$$\begin{aligned} &\text{high:} \quad \mathcal{A}(s,S) - \mathcal{A}(s,S-1) + \ .5\left[\mathcal{A}(s,S-1)^2 - \mathcal{A}(s,S)^2\right] \geq M(s,S)\,cd \\ &\text{low:} \quad \mathcal{A}(s,S) - \mathcal{A}(s-1,S) + \ .5\left[\mathcal{A}(s-1,S)^2 - \mathcal{A}(s,S)^2\right] \leq M(s,S)\,c. \end{aligned} \tag{6}$$

Inserting the aggregate and individual abatements the formulas above become

$$\begin{aligned} &\text{high:} \quad \underbrace{(s + d(S-1))^2}_{\text{term 1}} \geq \underbrace{(s+S-1)^4\left[(s+dS)^2/(s+S)^4 + 2/cM(s,S)\,d\right]}_{\text{term 2}} \\ &\text{low:} \quad \underbrace{(s-1+dS)^2}_{\text{term 3}} \leq \underbrace{(s+S-1)^4\left[(s+dS)^2/(s+S)^4 + 2/cM(s,S)\right]}_{\text{term 4}}. \end{aligned} \tag{7}$$

For a stable pure high cost coalition, *term 1* exceeds *term 2*. Obviously, *term 4* falls short of *term 2* for $d > 1$. In case of all low cost countries leaving the coalition (or not signing it), this would imply *term 1* $\geq$ *term 2* $>$ *term 4* $\geq$ *term 3*. However, for $d > 1$ it can be shown that *term 1* falls short of *term 3* which is a contradiction. Thus, at least some low cost countries enter a stable coalition. Q.E.D.

As the contradiction above holds for all $1 \leq s \leq n$, a stable coalition with some high cost countries requires that **all** low cost countries have signed the IEA. Consequently, stable coalitions can either be of type $(s^* = n, S^* \geq 1)$ or $(s^* \geq 2, S^* = 0)$.

4.2 Pure Stable Low Cost Coalitions

Obviously, low cost countries feel a stronger incentive to join an IEA than their high cost neighbors. Therefore, it is possible to design a stable IEA where at least all high cost countries are separated.

Proposition 2 *If $c \geq .8$ there always exists a unique stable pure low cost coalition.*

Proof: A stable pure low cost coalition $(s^* \geq 2; S^* = 0)$ is internally stable for low cost countries and externally for both cost types. There are two steps to show: First, a high cost country has no incentive to join a stable pure low cost coalition s^*, i.e. $P^o(s^*, S^* = 0, d) \geq P^s(s^*, S^* = 1, d)$. And second, the existence of a unique pure low cost coalition.

i) For $d \to 1$ the stability conditions of low and high cost countries are similar. As the coalition s^* is externally stable for low cost country the same holds for high cost countries, $P^o(s^*, S^* = 0, \lim d \to 1) \geq P^s(s^*, S^* = 1, \lim d \to 1)$. When all high costs countries are outsider $(S^* = 0)$, the payoff of the high cost countries $P^o(s^*, S^* = 0, d)$ is independent of d as the aggregate abatements $\mathcal{A}$ are calculated on a pure low cost base. The payoff for a potential high cost signatory is convex in d, with a minimum at $d^{\mathrm{MIN}} = \left[(s+1)^3/c - s^2\right]/(2s+1)$. For d below $d^0 = (s+1)^2/c - s$ the aggregate abatements are positive. For d beyond d^0 abatements become zero and thus $P^s(s^*, S^* = 1, d \geq d^0) = 0$ too. Furthermore, as $d^{\mathrm{MIN}} < d^0$ the payoff for a high cost signatory falls short of the outsider payoff (figure 1). Thus, high cost countries have no incentive to join stable stable pure low cost coalitions s^* and remain complete outsider $S^* = 0$.

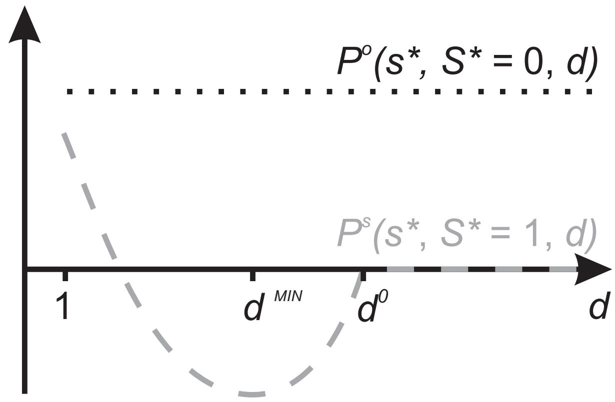

Figure 1: Incentive for staying aside

ii) Inserting the aggregate and individual abatements, internal and external stability of a pure low cost equilibrium $(s^*, S^* = 0)$ requires

$$\delta(s) := \frac{2s(s-1)^2}{s^2 + (s-1)^2} \leq c, \quad \text{and} \quad \delta(s+1) := \frac{2s^2(s+1)}{s^2 + (s+1)^2} \geq c. \tag{8}$$

As the δ function is increasing in s and $\delta(2) = .8$, there always exists a unique stable coalition s^* where both conditions in (8) hold simultaneously.

The case of a pure low cost IEA corresponds to the traditional literature on coalition formation (cf. Barrett (1992, 1994) or Carraro and Siniscalco (1993)) where all countries are symmetric in all respects.

4.3 Mixed Coalitions

As mentioned before, a stable coalition with some high cost countries requires that all low cost countries are signatories. Therefore, a mixed coalition $(s^* = n, S^* \geq 1)$ has to be internal stable for low cost countries, while both stability conditions are required for high cost countries. Intuitively speaking, whether an IEA with both types is stable or not depends on the number of low cost countries n and on the difference in marginal abatement cost d. It seems to be auspicious that a mixed coalition for few low cost countries (e.g. $n = 1$) with some high cost countries is stable. Moreover, if the countries are almost identical $d \to 1$ their stability condition are alike. These rather similar countries can be expected to form a mixed coalition.

A proposition and its proof is still work in progress.

5 Concluding Remarks

To be written

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