Cost sharing rules and international climate policy

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May 30, 2007

Preliminary version

Abstract

We study the distribution of emission ceilings in international climate policy. We link this problem with general cooperative games where an amount of resources must be divided among beneficiaries with unequal claims on the resources. We define the claims of the participants taking into account the principles of responsibility, capacity, need and contribution. Then, we propose a set of axioms and a distributional rule in order to solve the emission permits problem. We also extend the distributional rule to take into account the deepening and broadening of cooperation in international climate policy.

Keywords: Responsibility, capacity, need, contribution, emissions permits problem, distributional rule.
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1 Introduction

The purpose of the well-known Kyoto Protocol is to cut back emissions of greenhouse gases in the industrialized countries. The general goal is to reduce 1990 emissions in a 5.2% by the time period 2008-2012. In order to meet this general goal, however, the Protocol imposes different quantitative emissions ceilings on the industrialized countries and introduces flexible mechanisms to help countries to fulfill their obligations. The distribution of emissions ceilings brings about costs and benefits for the countries involved and was in the core of the negotiations held in Kyoto in 1997.

International environmental agreements such as Kyoto reflect the key role that international cooperation plays in the resolution of many environment problems, specially those related with climate policy. An effective cutback of emissions needs the involvement of many different countries. These agreements put an upper limit on total emissions and propose an emission ceiling for each country involved in the negotiation in order to meet this upper limit. The major challenge of the negotiators is to find some scheme for the emission ceiling distribution that can be generally accepted as "fair" by all or at least most of the involved countries (Ringius *et al.*, 2002).

There are many different rules of distribution that have been proposed in international negotiations. Some of them are simple rules such as the *flat rate reduction approach* or the *population-based approach* but others are more elaborated such as the *multi-criteria approach* or the *Triptych sectoral approach* (Phylipsen *et al.*, 1998).

Some of these approaches have been criticized because they do not consider the historical responsibility of countries in the pollution problem at hand. This is the case of the flat rate reduction approach, the equal-abatement-cost-based approach or the GDP-based approach. Other criteria are found to have a strongly distributive character such as the population-based approach. The more elaborate proposals try to skip some or all of these problems.

Distribution problems have been considered in other economic settings such as bargaining and cooperative games. There exists an extended literature on cooperative games and bargaining where different solutions have been proposed and axiomatically defended (see, for example, Moulin, 2002, for a survey). Our goal is to built a bridge between the axiomatic theory of cooperative games and international environmental negotiations.

Furthermore, the axiomatic approach considers how the formation of coalitions can affect the distribution of emissions permits and, consequently, the distribution of costs and benefits. This point is specially relevant to analyze the role of the European Union (EU) in the negotiation of Kyoto and the effect of the subsequent EU Burden Sharing Agreement on the European countries. Similarly, the axiomatic approach also provides a structure to analyze two points that were led aside in the negotiations of Kyoto: the deepening and broadening of cooperation. The axioms give some clues to analyze how a restriction in the number of permits to be distributed can be implemented (the deepening of cooperation) and it is also valid to study the incorporation of new agents to the treaty (the broadening of cooperation).

The paper is organized as follows. In the next section, we formally defined the emission permits problem with special attention to the definition of each country claim on the permits. The following section introduced some interesting axioms for the negotiation problem and proposes a solution to the emission permits problem that fulfills all this axioms. We also link this solution with the rules of distribution that have already been used in international environmental negotiations.

2 The emission permits problem

In a general emission problem, a given amount of emission permits must be divided among agents (usually countries) with unequal inherent rights on the permits. The goal of international negotiations is to achieve a fair distribution of permits that will be accepted by most of the countries. This problem is closely related to the *rationing problem* studied in cooperative games. In a rationing problem, a given amount of resources must be divided among beneficiaries with unequal claims on the resources. There is a large literature on this subject (see Moulin (2002) for a survey) where different solutions are proposed for the distribution of the resources among different agents. The formal definition of a rationing problem and his solution is the following,

Definition: a *rationing problem* is a triple (N, t, x) where N is a finite set of agents, the nonnegative real number t represents the amount of resources to be divided, the vector $x = (x_i)_{i \in N}$ specifies for each agent i a claim x_i and these numbers are such that

$0 \leq x_i$ for all i;

$0 \leq t \leq \sum_{i \in N} x_i$

A *solution* to the rationing problem is a vector $y = (y_i)_{i \in N}$, specifying a share y_i for each agent i and such that

$0 \leq y_i \leq x_i$ for all i;

$\sum_{i \in N} y_i = t$

In an emission permits problem the finite set of agents, N, is the set of countries involved in an international environmental negotiation.[1] The resource to be distributed is the total emission permits, E. This permits can be considered a good or a gain for the agents involved in the negotiations and can be represented by a nonnegative real number. However, the claims of the agents are not easy to define. As Moulin (2002) points out, in order to maintain the crucial inequality, $0 \leq y_i \leq x_i$ the claims, x_i should be objectively measured. In a emission permits problem, however, the claims of the agents will be subjective evaluation of needs if each country can choose his own claim. Moreover, the fairness of the distribution depends on the definition of the claims. In order to avoid these problems, we propose that the claims

[1] A similar reasoning can be used for a set of enterprises affected by domestic pollution measures.

of each country should be an objective measure. To find this measure, we analyze the different national circumstances that are relevant to burden differentiation and the different fairness principles that have been used in international climate policy (Phylipsen *et al*, 1998, Ringius *et al.*, 2002).

Following Ringius *et al.* (2002), we can point out four principles that are widely accepted as fairness principles in international climate policy: responsibility, capacity, need and contribution. The first one, the *principle of responsibility* says that the distribution of permits should take into account a party's share of responsibility for causing that problem. Historical emissions can be considered as a measure of the responsibility that a country has on the emission problem. The *principle of capacity* considers the distribution of costs according to the ability to pay. Wealth measured in terms of GDP (per capita) is a conventional measure used for determining capacity. The *principle of need* states that all human beings should be granted the 'pollution permits' needed to secure basic human needs. Population is then a good measure of the need of each country. Finally, the *principle of contribution* takes into account a party's share of contribution to solving the problem, that is, the domestic measures already taken by a country to solve the pollution problem at hand.

Therefore, the are at least for variables that should be taken into account in the constructions of the objective claims of a country I involved in international negotiations: historical emissions, H_i, population, Z_i, gross domestic product, GDP_i and domestic measures, D_i. As a first approximation to the emissions problem, we consider that the individual claims are vectors whose components are these four variables, that is, the claim of country i is $x_i = (H_i, Z_i, GDP_i, D_i)$. More over, as the aim of the international negotiations is the reduction of total emissions, we can state that $E < \sum_{i=1}^{n} H_i$. We can now formally defined the emission permits problem.

<u>Definition</u>: a *emission permits problem* is a triple (N, E, x) where N is a finite set of agents, the nonnegative real number E represents the amount of permits to be divided and the matrix of claims $x = (x_i)_{i \in N}$ specifies for each agent i a claim x_i. Each claim is a vector such that

$x_i = (H_i, Z_i, GDP_i, D_i)$;

$0 \leq H_i$, $0 \leq Z_i$, $0 \leq GDP_i$, $0 \leq D_i$ for all i;

$0 \leq E < \sum_{i \in N} H_i$

A *solution* to the rationing problem is a vector $y = (y_i)_{i \in N}$, specifying a share y_i for each agent i and such that

$0 \leq y_i$ for all i;

$\sum_{i \in N} y_i = E$

According to this definition, a country can obtain more permits that his corresponding historical emissions, H_i. That is, the solution of the emission problem can lead to the reduction of emission for some countries (whenever $y_i < H_i$ for a country i) and to the possibility of incrementing the emissions for others (whenever $y_i > H_i$ for a country i).

3 The distribution of permits

3.1 Some interesting axioms

There are some properties that a rule for the distribution of permits should fulfill. Leaving aside the principles of responsibility, need, capacity and contribution, the negotiation process should be blind to action of coalitions or to the reallocation of demands. The following definitions and axioms capture these ideas.

Let S be a subset of N, $S \subseteq N$, where all agents in S have merged into a single agent S^*. $N^{[S]}$ is the set with $(|N| - |S| + 1)$ agents. Denote $x_S = \sum_{i \in S} x_i = (\sum_{i \in S} H_i, \sum_{i \in S} Z_i, \sum_{i \in S} GDP_i, \sum_{i \in S} D_i)$. We define $x_i^{[S]} = x_i$ if $i \notin S$, $x_{S^*}^{[S]} = x_S$.

No Advantageous Reallocation NAR (Moulin, 2002)

For all N, S, all E and all x, x': $x^{[S]} = x'^{[S]} \Rightarrow r_S(N, E, x) = r_S(N, E, x')$

Irrelevance of Reallocations IR (Moulin, 2002)

For all N, S, all E and all x, x': $x^{[S]} = x'^{[S]} \Rightarrow \{r_j(N, E, x) = r_j(N, E, x')$for all $j \in N/S\}$

Independence of Merging and Splitting IMS (Moulin, 2002)

For all N, S, all E and all x: $r(N, E, x)^{[S]} = r(N^{[S]}, E, x^{[S]})$

NAR indicates that the reallocation of individual demands among the agents in S, does not change the total share of this coalition, thus preventing such maneuver to be profitable. Similarly, IR establishes that the reallocation of demands do not affect agents outside the scope of the reallocation.

These four axioms, NAR, IR, IMS are quite interesting if we consider the possibility of some countries forming a coalition in order to negotiate an environmental agreement. For example, the European Union forms a coalition in the Kyoto Protocol. These axioms proclaim that this position should not alter the distribution of permits of countries outside the coalition (IR) and should not affected the total allocation of the EU (NAR).

3.2 A general proposal for the distribution of permits

There are different burden sharing formulas that have been used to distribute rights to pollute. Phylipsen *et al.* (1998) and Rose *et al.* (1998) present a complete list of formulas for the distribution of emission permits. Moreover, the axiomatic analysis of cooperative games shows that the proportional method is the rationing method meeting any one of the four above axioms (Moulin, 2002). Therefore, we are interested in a proportional distributional rule to solve the emission problem.

Proportionality has been used in different burden sharing formulas. For example, the sovereignty criteria says that all nations have an equal right to pollute and to be protected from pollution. This principle has lead to a general operational rule proposing a proportional cut back in emissions across all nations, that is, the operational rule for emission permits is to distribute permits in proportion to emissions

(Rose *et al.*, 1998). Other criteria are also based in a proportional distribution of permits, for example, the egalitarian criteria, grandfathering or the Kantian rule. The difference between these methods is the definition of the claims of the countries. In the egalitarian criteria, for example, proportions are made according to population. Grandfathering and the Kantian rule are equivalent to the sovereignty rule (see Rose *et al.*, 1998). The following proportional method merges all these ideas.

Definition: the *proportional method* is defined as follows:

$$y = pr(N, E, x) = \left[h\frac{H_i}{\sum_{i=1}^{n} H_i} + z\frac{Z_i}{\sum_{i=1}^{n} Z_i} + k\frac{1/GDP_i^*}{\sum_{i=1}^{n} 1/GDP_i^*} + d\frac{D_i}{\sum_{i=1}^{n} D_i}\right] E$$

where $GDP_i^* \equiv GDP_i/Z_i$, with $h + z + k + d = 1$ and $h \geq 0$, $z \geq 0$, $k \geq 0$, $d \geq 0$.

This proportional method includes different national circumstances in the calculation of emissions ceilings and gives them different weights. Our proposal is close to the multi-criteria approach (Phylipsen, 1998) where the results are influenced by the weighting factors used. In our rule, the different weights are also related with the fairness principles: responsibility, need, capacity and contribution. It is easy to observe that this rule fulfills the above axioms.

3.3 Link to well-known rules

Observe that h is the weight that historical emissions have in the distribution of permits and recall that this emissions are a approximate measure of the responsibility of a country in the problem at hand. Moreover, if $h = 1$ the proportional method is reduced to the following expression:

$$y = pr(N, E, x) = \frac{H_i}{\sum_{i=1}^{n} H_i} E$$

That is, permits are distributed in proportion to historical emissions. This is the well-known *sovereignty rule*. In this case, it is impossible for a country to get more permits that his historical emissions. It is also interesting to notice that those countries with greater historical emissions receive more permits, y_i, but also have to reduce more, $(H_i - y_i)$.[2] However, when $h = 1$ and the permits to be distributed represent a percentage p of the total historical emissions, each country reduces the same percentage $(1-p)$ of its historical emissions, that is, the permits of each country are $y_i = pH_i$, for all i.

Similarly, z represents the weight that the population of a country has on the distribution of permits. This is directly related with the principle of need. In fact, when $z = 1$ we only consider population in the distribution of permits and this lead us to the *egalitarian criteria*: all people has equal right to pollute and to be protected from pollution and, therefore, emissions should be distributed in proportion to population (Rose *et al.*, 1998). The proportional method is them,

$$y = pr(N, E, x) = \frac{Z_i}{\sum_{i=1}^{n} Z_i} E$$

[2]This point can be seen defining the dual problem, r^*. When $h = 1$, $r^*(N, E, x) = H - r(N, H_N - E, x)$, where $H_N = \sum_{i=1}^{n} H_i$. We consider the distribution of reductions (a bad), $H_N - E$, , instead of the distribution of the permits (a good), E.

Observe that, when $h = 1$ we don't exclude the possibility of countries receiving more permits that his historical emissions, $y_i > H_i$.

On the other hand, k represents the weight that the ability to pay has on the distribution of permits. To determine the capacity of each agent we use the GDP per capita. When only the ability to pay is considered in the distribution of permits, we are giving priority to the principle of capacity. In such a situation $k = 1$ and the proportional method is reduced to the following expression,

$$y = pr(N, E, x) = \frac{1/GDP_i^*}{\sum_{i=1}^{n} 1/GDP_i^*} E$$

According to this distributional rule, a country with a certain GDP per capita receives less permits than a country with lower GDP per capita. In fact, the relationship between the permits received by each country, y_i, and its GDP per capita, GDP_i^* and the permits and GDP per capita of another country j is $\frac{P_i}{P_j} = \frac{GDP_j^*}{GDPi^*}$.

To capture the effect of the principle of contribution, that is, to take into account the the benefits of solving a problem or providing a good should be distributed in proportion to a party's share of contribution, we must define variable D. The energy efficiency can be considered as a proxy of this variable. Energy efficiency has been defined as emissions per unit of GDP (see Ringius *et al.*, 2000), that is, $D_i = \frac{E_i^t}{GDP_i^t}$. Those with greater energy efficiency should receive more permits as this energy efficiency can represent previous investment in the abatement of emissions. The value of parameter d measures the value that energy efficiency and the principle of contribution has on the distribution of emission permits.

Whenever $0 < h < 1$, $0 < z < 1$, $0 < k < 1$, $0 < d < 1$, we are giving positive weights to the four principles, responsibility, need, capacity and contribution and using a multi-criteria approach to the distribution of permits. The axioms that we have introduced say that, given the value of the parameters, h, z, k and d, the distribution of permits is blind to the formation of coalitions. However, if a group of countries form a coalition, they can redistribute the permits received by the whole coalition using other parameter values or even other distributional method, as long as they meet the ceilings imposed to the coalition by the international agreement.

3.4 The deepening of cooperation

The deepening of cooperation is important for additional reductions of emissions. For example, the initial proposal of the Kyoto Protocol must be fulfill by period 2008-2012. From them on, a new and more restrictive proposal will be negotiated. This future proposal is relevant to make a deeper effort on the restriction of greenhouse emissions but also for the enforcement of the actual proposal. Which is the role of the actual emission ceilings in the future negotiations?

The actual distribution of emission permits, $y = (y_i)_{i \in N}$, must condition the posterior claims of the subjects. Otherwise, incentives not to meet the corresponding ceiling could be created. The goal of the emission permits problem is to reduce historical emissions as we have assumed that $0 \leq E \leq \sum_{i \in N} H_i$. The new proposal is to achieve deeper cooperation, that is $E' < E$. Assume that a country does not meet the objective for period t and its emissions are $E_i^t > y_i$. The historical emissions in the claim of this country for the subsequent negotiation should be y_i and not E_i^t. Otherwise, no country would have incentives to meet its ceiling, y_i.

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