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## ► To cite this version:

Frederic Chantreuil, J. Cooper. Setting the initial allocation of marketable emission permits. Journées Economie de l'environnement : L'efficacité des politiques publiques face à la gestion de l'environnement et des ressources renouvelables, Dec 1999, Strasbourg, France. 15 p. hal-01593998

**HAL Id: hal-01593998**

**<https://hal.science/hal-01593998>**

Submitted on 7 Jun 2020

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## Setting the Initial Allocation of Marketable Emission Permits

F. Chantreuil<sup>1</sup> and J. Cooper<sup>2</sup>

### 1. INTRODUCTION

Article 17 of the Kyoto protocol allows international emissions trading among the signing parties with quantified emission reduction targets. The precept of emissions trading is to use the efficiency of the market place to achieve environmental objectives at the lowest possible cost. Under an international emissions trading rule, a country, or a firm, would be able to face its emissions reduction target by reducing pollution itself, purchasing reductions from another country, or firm, that was able to achieve excess gains, or some combination of both. This paper focuses on the setting of the reduction targets. Specifically, given that the Kyoto Protocol allows cooperation between countries in achieving emission reductions, we examine the impacts of cooperation between countries on the setting the emission targets.

If the Kyoto protocol is at all representative of international treaties involving the sharing of some burden, the Protocol will use a fairly basic means for the agreeable distribution of burdens across countries.<sup>3</sup> Betram (1992), Grubb and Sebenius (1992), and Epstein and Gupta suggest a variety of alternative allocation mechanisms, including allocations based on GNP, real GNP, total population, adult population, land area, and emissions. Countries will naturally support the criterion that give them the smallest reductions. Hahn and Stavins note that several criteria may need to be blended to create international consensus on emission allocations.<sup>4</sup> For example, while developing countries will have relatively little incentive to participate unless they receive economic benefits from an agreement, developed countries will want to ensure that their allocations are generated in ways that they perceive as equitable.

<sup>1</sup> INRA-ESR, rue Adolphe Bobierre, CS 61103, 35011, Rennes cedex, France.

<sup>2</sup> Economic Research Service (United States Department of Agriculture), 1800 M Street, NW, Washington DC, 20036-5831, USA.

<sup>3</sup> For example, each United Nations member's burden of that institution's budget is a scale closely based on their share of world gross national product.

Most proposals for allocating control obligations among nations call for proportionately higher rates of reduction in emissions by industrialized countries (and among industrialized countries, by the United States) and for substantial reductions in the predicted rates of increase in carbon dioxide emissions by most developing countries.

The economics of agreements on global warming has been theoretically examined using two-country non-cooperative game theory models (e.g., Chen, 1997; Caplan, A, C. Ellis, and E. Silva, 1999). This paper takes a different track and uses cooperative voting game concepts. Cooperative game theory is especially relevant to analysis of the Kyoto Protocol given that it grants permission to the Parties to the Protocol to reach their targets collectively rather than individually, as long as the combined emissions do not exceed the sum of their commitments. Cooperative game theory provides a means to analytically express the basic principals for determining allocation rules over an economic "pie" that address the demands of interest groups and of economic efficiency. Consider a three person problem. The difference over the two person case is that coalitions are possible. That means that two players can manipulate the outcome of the game acting together against the third. To take into account the possibility to form coalitions, we appeal to n-person cooperative game theory for developing models determining initial emission permit allocation, at the country, regional, and Protocol administrator levels.<sup>5</sup>

Our focus is on equity considerations in setting the reduction targets; an allocation based on this economic efficiency criteria may not be particularly relevant at the international level, where equity considerations are a prime concern (Hagem and Westskog, 1998). For example, in an international environmental treaty, heavy use of side payments may be not a politically acceptable instrument for distributing permits. Hence, even if subsequent trading leads to a cost-effective outcome whatever the initial allocation, countries will care about the initial allocation. However, the allocation rules we propose allows part of the burden to be based on equity considerations and the rest on the basis of economic efficiency. For various scenarios regarding the level of bargaining power among the players, we assess the impact of these allocation rules on the distribution of the burdens.

## 2. THE MODEL

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<sup>4</sup> As an example, Hahn and Stavins note that the Canadians proposed the use of population and GNP combined as allocation criteria when CFC reduction obligations were being considered in the development of the Montreal Protocol.

<sup>5</sup> The regional level refers to coalitions that countries may form in the marketing of permits. Alternatively, the analysis can be done at a more micro-level at the producer, regional (sub-country), and country levels within the group of countries participating in the protocol.

Considering the emissions reduction problem, some argue that no single nation should initiate a directed course of action until there is a global framework with worldwide warrant. Others argue that a global response is, in effect, just a sequence of national responses, and that it is incumbent upon individual nations to begin taking steps to reduce their own emissions now. The Kyoto Agreement shows that in reality we will have to go down both paths simultaneously. Nevertheless, some countries have not signed the Agreement, not because they oppose setting a global limit on carbon emissions, but because they would like developed nations to pay the cost of reducing emissions. The perception in some developing countries is that they did not cause the current mess and should not have to pay for it. At the core of the developing country view is the notion of fairness. Is it fair, some ask, for the countries with far lower GDP and per capita GDP to be asked to take on obligations to deal with a global problem caused thus far by the emissions from the developed world?

This point of view is natural, since the initial distribution of emissions commitments under the Kyoto Protocol has important implications for the level of emissions reduction effects that countries will undertake. In all existing trading systems, the initial allocation of allowances, which forms the baseline for trading, has proved to be one of the most contentious issues. One approach is to take emissions level at some point in the past and then apply a uniform reduction factor to establish allowance. This approach was taken by the European Union (EU) in its initial negotiating position for the Kyoto Protocol.

Restated formally, if  $Q_j$  denotes the reference emissions of a given country  $j$ , the emission quantity authorized for this country will be:

$$q_j = \delta Q_j, \text{ with } 0 < \delta < 1 \quad (1a)$$

where  $1 - \delta$  represents the reduction rate that is constant across all countries.

The total allowances are then

$$\sum_j q_j = \delta \sum_j Q_j \quad (1b)$$

Obviously, in equity terms, this allocation rule has a superficial appeal. In fact, it does not take into account national circumstances that vary among the different countries, e.g. the number of firms, the GDP, the per capita GDP, and

the population of each country.<sup>6</sup> The Protocol remains politically controversial and legislative approval is by no means guaranteed (IEA). Hence, it would be useful for the success of the Protocol to propose rules for setting reduction targets that allows more explicit balancing of political and economic interests.

To determine the allocation of initial allowances that explicitly accounts for the characteristic of the countries, we propose to use a payoff function, denoted as  $\Phi$ , that derives from an n-person co-operative games construct. This co-operative games construct implies, implicitly, that the determination of such an allocation can be achieved if all countries agree to delegate their decision power to an international institution for the definition of the agenda and the type of emission permits market that can be implemented. In other words we suppose that all countries accept the fact that the United Nations Climate Change Commission has to allocate the initial endowments to each country.

Hence, the problem of emissions right allocation can be set in the form of a simple game in characteristic function form  $(N, U)$ , i.e., with side payments, where  $N$  is the set of players (i.e. countries) and  $U$  the characteristic function of the game<sup>7</sup>. In the climate change negotiation context, this side payments assumption expresses the possibility for countries to form blocks that will meet the aggregate emission level of the countries forming the block. The characteristic function sums up all possible utility sets of every coalition  $S \subseteq N$ . For example, if population is the relevant criterion, we need to be able to calculate it for all possible coalitions. If  $PO(S)$  represents the population of coalition  $S$  we have the following simple game with the characteristic function  $U(S)$

:

$$\text{For all } S \subseteq N, U(S) = \begin{cases} 1 & \text{if } PO(S) \geq \beta \cdot PO(N) \\ 0 & \text{otherwise} \end{cases} \quad (2)$$

with  $0 < \beta < 1$ . For example, a value of  $\beta = 0.5$  means that a coalition  $S$  can obtain the total emissions allowances if its population is equal or greater than 50 percent of the United Nations population  $PO(N)$ .

Given this framework, the Shapley allocation approach is particularly useful to solving the model (see Roth Ed., 1988 for Shapley's paper, which was first published in 1953 and for a survey on extension works; Mas-Colell,

<sup>6</sup> Equations 1a and 1b are in fact slight simplification taken for clarity as in the proposed reduction targets under the Kyoto Protocol, the three possible obligations  $\bar{\alpha}$  are possible: 0.95 for Annex I countries, 0.92 for most countries, and 0.93 for the U.S.

<sup>7</sup> The side payment assumption implies the existence of commodities that are linearly transferable. In other words, the utility functions for the individuals can be chosen so that the rate of transfer of utility among any two of them is 1:1. Hence, the total utility obtainable by a coalition  $S$  can be divided among the members of this coalition in any number of possible ways.

Whinston, and Green). This normative concept attempts to describe a fair way to allocate gains from cooperation, given the strategic realities captured by the characteristic form. The Shapley value in our case represents the final distribution of initial allocation of emission permits between all countries. A lengthy discussion of Shapley values is outside the scope of this paper. Briefly, the Shapley value summarizes the complex possibilities facing each player  $i$  (i.e. country) in game  $(N, U)$  by a single number  $\varphi_i(N, U)$  representing the value to  $i$  of playing the game. Thus the value of game  $(N, U)$  is an  $n \times 1$  vector in which each element represents the “expected value” to a player of playing the game, where  $\varphi_i(N, U)$  represents the expected payoff to player  $i$  under a randomization scheme on all coalitions  $S$  she can join. For a simple two player case, the egalitarian solution is represented by the expression  $\varphi_1(N, U) - \varphi_2(\{1\}, U) = \varphi_2(N, U) - \varphi_1(\{2\}, U)$ , where  $\varphi_1(N, U) + \varphi_2(N, U) = U(N)$ . This relationship says is that in the egalitarian Shapley value solution, player 1 gets the same utility out of the presence of player 2 as the latter gets out of the former. Extending this concept to a multiple player game, the general formula is (see e.g., Mas-Colell, Whinston, and Green):

$$\varphi_i(N, U) = \sum_{\substack{i \in N \\ i \notin S}} \frac{s!(n-s-1)!}{n!} [U(S \cup \{i\}) - U(S)] \quad (3)$$

where  $s$  is the number of players in a coalition  $S$ . The basic principle (marginality principle) behind the share  $\varphi_i(N, U)$  is that when a player joins a coalition she receives the marginal amount  $[U(S \cup \{i\}) - U(S)]$ . The probability that a random ordering of coalition  $S \subset N$  forms as the union of  $i$  and its predecessors equals the probability that  $i$  is in the  $s^{th}$  place, which is  $\frac{1}{n}$  multiplied by the probability that  $S - \{i\}$  forms when we randomly select  $s - 1$  members from  $N - \{i\}$ , which is  $s!(n-s-1)!$ . For any given random ordering of players, we calculate the marginal contribution of every player  $i$  to its set of predecessors in this ordering.

Consider the simple game denoted in (2) between five producers  $(a, b, c, d, e)$  whose population amounts respectively to 5, 15, 20, 25, and 35. If  $\beta = 0.5$ , then the Shapley value of this game is  $\left(\frac{1}{30}, \frac{7}{60}, \frac{1}{5}, \frac{1}{5}, \frac{9}{20}\right)$ .

Note that the Shapley value is the same for country  $c$  and  $d$ , even though the population of country  $d$  is larger. This results describes a fundamental concept behind the Shapley value: since player  $d$  has no greater opportunity than  $c$  to

form a minimal winning coalition, he must have the same share as player  $c$  in a bargaining game. In contrast, the "vote vector" result --- payoffs strictly proportional to each person's share of the total population, i.e. no country has majority power on his own --- is  $\left(\frac{5}{100}, \frac{15}{100}, \frac{20}{100}, \frac{25}{100}, \frac{35}{100}\right)$ . As an example of the implication of the choice of  $\beta$ , suppose that in the vote vector, a player has a weight of 0.55 (55%). For  $\beta = 0.5$ , it has all the power. As  $\beta$  increases in the range  $0.55 < \beta < 1$ , the power of this player decreases, and when  $\beta = 1$ , all the players have the same power. The relative impact of changing  $\beta$  is data set specific.

The Shapley value can address the distribution of initial endowments between countries, but, most of the time and this is certainly true for the global climate change problem, negotiations held not only between Heads of each delegation, but also between Heads of State from their capitols. Perhaps the best illustration of this phenomenon is that while the President of the United States has signed the Kyoto Agreement, the treaty has not been ratified by the U.S. Senate. In fact, it is clear that those in industry most opposed to dealing with the climate change have thoroughly worked the political system to cast doubt on the science; and emphasize the possible negative economic impacts of the Kyoto Protocol. Obviously, the Shapley value is not the appropriate co-operative game theory model for determining initial emission permit allocation, at the country, regional, and Protocol administrator levels. The Shapley value can address the distribution of initial endowments between countries, over which the members of each country (firm, sub-county,...) would bargain with each other to determine the division of the share received by their country. The main question now is how can we capture bargaining within countries. Put differently, how can we determine allocation rules that address the demands of interest groups and of economic efficiency. Considering the previous five countries example, we want to be able to compute the power sharing when, for example, countries  $a$  and  $b$  act together. Co-operative game theory provides a means to analytically express the basic principals for that purpose. To take into account that the negotiations held at several levels, we assume that fictitious delegates are elected to represent each country and each region. In that case, the set of players is denote as  $N = \{1, \dots, i, \dots, n\}$  which represents the set of firms (for example). The regions and the countries they belong to are denoted by the level structure  $B = \{B^1, B^2\}$ , where  $B^1 = \{C_1, \dots, C_m\}$  is the set of all countries and  $B^2 = \{R_1, \dots, R_g\}$  the set of all regions that describe  $N$ 's a priori coalition structure. Given this coalition structure framework, if we assume that in

each country  $j$ ,  $C_j \in B^1$ , a delegate is selected to represent the coalition, the bargaining situation is a problem of how to divide the emission permits and can be formally represented by the quotient  $(M, V) = (N, U) / B^1$ , where  $(M, V)$  is a game with a set of players (country representatives)  $M = \{1, \dots, j, \dots, m\}$  and its characteristic function is given by :

$$V(S) = U\left(\bigcup_{j \in S} C_j\right) \text{ for all } S \in M \quad (4)$$

Thus a reasonable expectation for the  $j^{th}$  country is the amount  $\phi_j(M, V)$ , which is the element in the Shapley value corresponding to player  $j$  in game  $(M, V)$ , and would be the value normally expected by this country.

Then, in each countries, the emission permits this country receives must be divided among regions and firms. Obviously, the payoff a player (i.e. a firm) receives depends crucially on the definition of the bargaining relationships between regions and between firms. To address this topic, in the following subsections, we propose three bargaining and payoff principle scenarios that are based on the same bargaining relationship among countries but that bargaining scenarios can vary among regions and among producers. The scenarios depend on the capacities of threat (bargaining power) of some regions over other regions within the same country or on the capacity of threat of a firm toward other firms within the same region. Section 2.1 presents a payoff function  $\Psi_1$  for a base scenario in which we consider only the amount each producer can obtain on his own. Section 2.2 presents a payoff function  $\Psi_2$  that captures the “lobbying game” between regions as played out in United Nations. Section 2.3 defines a payoff function  $\Psi_3$  motivated by the subsidiarity principle. In these three scenarios, to determine the final distribution of initial endowments in a manner that take into account interest firms of various types, various regions, and various countries, we assume a three-step process. In the first step, the countries bargain with each other to determine the division of the surplus. In the second step, the regions belonging to the same country bargain with each other over the allocation received by their country. Finally, the producers of a given region divide among themselves the share the region receives. However, because the Shapley value formula in (3) does not take into account the fact that the producers are organized a priori into level structure  $\mathbf{B}$ , the model must be extended for determining the sharing of emission permits.



## 2.1. Null threat and egalitarian principle

Since in this minimum information game we only account for the amount a player can obtain himself (that is his value in the characteristic function) and the amount the coalition to which he belongs to can obtain, this player has “no power” to negotiate with other players in the same coalition. Hence the term “null threat”. The term “egalitarian principle” is a technical one. For example, since US is not a winning coalition at the international level, the value of the characteristic function for the US regions is always the same (zero in this case) so the division of the emission permits US receives is an egalitarian one. As in the five countries example, no player has no greater opportunity than another player to form a minimal winning coalition. Hence every player has the same power, and the symmetry axiom of the Shapley value implies that all players will obtain the same share. In other words, this first allocation rule supposes that each region and each firm accept passively the emission permits allocation proposed by the United Nations.

Formally, the first bargaining procedure within countries originates when we simply take into account the amount  $U(K)$  that every coalition of regions  $K$  (such as  $K \subseteq C_j$ ,  $K \in B^2$ ) can obtain on its own. For this game, we can define the subgame  $(N_{C_j}, W_{C_j})$  in country  $C_j$ , where  $N_{C_j}$  represents the set of regions in country  $C_j$ . The characteristic function of this subgame is given by :

$$W_{C_j}(\emptyset) = 0 \quad (5)$$

$$W_{C_j}(K) = U(K) \text{ for all } K \subseteq C_j, K \in B \quad (6)$$

$$W_{C_j}(C_j) = U(C_j) \quad (7)$$

Equation (5) says that the empty set is worth nothing and (7) says that the amount a coalition  $K$  (a region) can itself obtain in the subgame, defined on the country that  $K$  belongs to, is the same amount  $K$  can obtain in the initial game. Given these equations, a reasonable expectation for the region  $R_h \subset C_j$  is the amount  $\phi_h(N_{C_j}, W_{C_j})$ , which is the Shapley value of player  $h$  in the subgame  $(N_{C_j}, W_{C_j})$ .

We can use the same reasoning to divide the amount received by the region  $R_h \subset C_j$  among the firms of this region. Thus, each firm  $i \in R_h \subset C_j$  can obtain the amount  $\varphi_i(N_{R_h}, W_{R_h})$ , which is the Shapley value of firm  $i$  in the subgame defined on the region  $R_h \subset C_j$ .

For this bargaining game, we can define a payoff function  $\Psi^1$ , in which the share a firm  $i \in R_h \subset C_j$  will receive is (see Chantreuil 1999):

$$\begin{aligned} \Psi_i^1(N, U) = & \sum_{\substack{G \subset R_h \\ i \in G}} \frac{g!(r_h - g - 1)!}{r_h!} [U(G \cup \{i\}) - U(G)] \\ & + \frac{1}{r_h} \left[ \sum_{\substack{K \subset C_j \\ R_h \notin K}} \frac{k!(c_j - k - 1)!}{c_j!} [U(K \cup R_h) - U(K)] - U(R_h) \right] \\ & + \frac{1}{r_h} \left[ \frac{1}{c_j} \left[ \sum \frac{s!(m - s - 1)!}{m!} [U(S \cup C_j) - U(S)] - U(C_j) \right] \right] \end{aligned} \quad (8)$$

where  $m$  denotes the number of countries,  $s$ ,  $k$ , and  $g$ , are the number of players in every coalition of countries  $S$ , every coalition of regions  $K$ , every coalition of firms  $G$ , respectively.  $c_j$  represents the number of regions in the country  $C_j$  and  $r_h$  the number of firms in the region  $R_h$ .

Consider the example of the five countries with population criterion. If we take into account the fact that players  $a$  and  $b$  act together, the payoff vector using the allocation rule  $\Psi^1$  will be  $\left( \frac{1}{12}, \frac{1}{12}, \frac{1}{6}, \frac{1}{6}, \frac{1}{2} \right)$ .

## 2.2. Strong threat and the quotient game lobbying principle

The payoff function in this section uses more information than in the first, given that here we need to know the amount a region can obtain by forming a coalition with other countries, an amount that is different for each country. Hence, the degree of bargaining power varies among the countries, which produces the demand for lobbying activities. This bargaining procedure within countries consists in accounting for the amount  $U(K)$  that every coalition  $K$  (such as  $K \subseteq C_j$ ,  $K \in B^2$ ) can obtain itself and the amounts  $U(K \cup C_q \cup \dots \cup C_m)$  that  $K$

could obtain if it would replace country  $C_j$  and form a coalition with one or more of the remaining countries of  $B^1$ .

A region can threaten to leave a coalition on the basis of being able to gain more elsewhere. Of course this is not a real threat and is never carried out but it can be used to compute the relative power of each region in a given country, and as such, it captures much of the “lobbying game” of regions at the international level.

Formally, for any  $K \subset C_j$ , and  $K'$  its complement relative to  $C_j$ , we define a restricted game

$(M|C_j/K, V_{C_j/K})$  as representing the quotient game  $(M, V)$  when  $K$  replaces the country  $C_j$  in  $B^1$ . This

restricted game is the formal representation of a bargaining situation which involves  $K$  and the other countries. Its characteristic function is given by

$$V_{C_j/K}(S) = U\left(\bigcup_{q \in S} C_q - K'\right) \text{ for all } S \subseteq M|C_j/K \quad (9)$$

where  $M|C_j/K$  represents the set of players when country  $C_j$  is replaced by  $K$ . Given this function, a

reasonable expectation for  $K$  is the Shapley value  $\varphi_K(M|C_j/K)$  of player  $K$  in this restricted game. This

amount also represents the relative payoff, in game  $(N, U)$ , of  $K$  if it would replace the country  $C_j$  and bargain with the  $m-1$  other countries.

Using the measure of the relative payoff of each region of the country  $C_j$ , we can define the subgame  $(N_{C_j}, W_{C_j})$

of country  $C_j$  by its characteristic function given in (5), (7) and by:

$$W_{C_j}(K) = \varphi_K(V_{C_j/K}) \text{ for all } K \subseteq C_j, K \in B^2 \quad (10)$$

Thus, each region  $R_h \subseteq C_j$  can obtain the amount  $\varphi_h(N_{C_j}, W_{C_j})$  which is the Shapley value of player  $h$  in the subgame  $(N_{C_j}, W_{C_j})$ .

To determine the division of the amount received by the region  $R_h$  among the firms of this region, we use the same argument. Each firm  $i \in R_h \subset C_j$  can obtain the amount  $\varphi_i(N_{R_h}, W_{R_h})$ , which is the Shapley value of player  $i$  in the subgame defined on region  $R_h$ .

Given this subgame, we can define a payoff function  $\Psi^2$  in which the share a firm  $i \in R_h \subset C_j$  will receive is given by the following formula (Chantreuil, 1999) :

$$\Psi_i^2(N, U) = \sum_{\substack{S \subset M \\ C_j \notin S}} \sum_{\substack{K \subset C_j \\ R_h \notin K}} \sum_{\substack{G \subset R_h \\ i \notin G}} \frac{s!(m-s-1)!k!(c_j-k-1)!g!(r_h-g-1)!}{m!c_j!r_h!} [U(S \cup K \cup G \cup \{i\}) - U(S \cup K \cup G)] \quad (11)$$

With the five countries game example, if we take into account the fact that players  $a$  and  $b$  act together, the payoff vector using the allocation rule  $\Psi^2$  will be  $\left(\frac{1}{24}, \frac{3}{24}, \frac{1}{6}, \frac{1}{6}, \frac{1}{2}\right)$ .

### 2.3. The subsidiarity principle

Finally, we can define a third payoff function that assumes that the problem of the United Nations is only to determine the emission permits allowance for each country. This assumption can be motivated by the principle of subsidiarity, which basically means that the United Nations does not make decisions at the individual level. Instead, the country itself has to solve problems at this level. In this case, as discussed in section 2, the payoff vector we are looking for corresponds to the Shapley value of the quotient game  $(M, V)$  played by the delegates of each country.

The share every country  $j \in M$  will receive is given by:

$$\varphi_j(M, V) = \sum_{\substack{S \subset M \\ j \notin S}} \frac{s!(m-s-1)!}{m!} [V(S \cup \{j\}) - V(S)] \quad (12)$$

Once this payoffs vector is defined, the United Nations consider the problem solved at the International level. Then, with respect to the principle of subsidiarity, each state can choose its own emission permits allocation process regardless of what the others do. We can set this problem of the division of the gain among the regions of a given

country in the form of a simple game. Hence, the share a region will obtain corresponds to the Shapley value of the game defined on the country of interest.

Using the same argument for the allocation of emission permits within each region, we can define a payoff function

$\Psi^3$  in which the share a firm  $i \in R_h \subset C_j$  will receive is given by (see Mathurin 1997):

$$\begin{aligned} \Psi_i^3(N, U) = & \sum_{\substack{G \subset R_h \\ i \in G}} \frac{g!(r_h - g - 1)!}{r_h!} [V_{R_h}(G \cup \{i\}) - V_{R_h}(G)] \\ & + \frac{1}{r_h} \left[ \sum_{\substack{K \subset C_j \\ R_h \notin K}} \frac{k!(c_j - k - 1)!}{c_j!} [V_{C_j}(K \cup R_h) - V_{C_j}(K)] \right] \\ & + \frac{1}{r_h} \left[ \frac{1}{c_j} \left[ \sum \frac{s!(m - s - 1)!}{m!} [V(S \cup C_j) - V(S)] - V_{C_j}(C_j) \right] - V_{R_h}(R_h) \right] \end{aligned}$$

where  $(N_{R_h}, V_{R_h})$  is the simple game defined on the region  $R_h$  and  $(N_{C_j}, V_{C_j})$  is the simple game defined on the country  $C_j$ . With the five firm game example, if we take into account the fact that players a and b act together, the

payoff vector using the allocation rule  $\Psi^3$  will be  $\left(0, \frac{1}{6}, \frac{1}{6}, \frac{1}{6}, \frac{1}{2}\right)$ .

### 3. DISCUSSION

In order to control the global warming gases phenomenon, most of the UNFCC participants have signed an agreement setting a target level not to exceed the year 2007. Although all countries agree to set a global limit on carbon emissions, some have not signed the agreement. The main disagreement refers to the global system of tradeable carbon dioxide permits, qualified as being immoral and unfair by a number of developing countries. Unfortunately, there is no consensus on the best definition of fairness, or equity, but the negotiation process can be facilitated if countries understand the full ramifications of various alternatives (cf. Rose and Stevens, 1998). Nevertheless, there is a range of research works in social choice and welfare theory, equity theory and co-operative game theory dealing with the definition of criteria such as equity and fairness. While efficiency-equity tradeoffs

receive substantial attention in the mainstream economics literature, equity concerns do not receive their due in the resource economics literature. Certainly, from a pure economics standpoint, equity tend not to be a strong mechanism for making allocations, and we prefer to be efficient and present allocations that maximize consumer plus producer surplus. Realistically however, political realities can require equity concerns to be of important, or even prime concern. The Shapley value format we use for our co-operative games solutions is efficient in the class of equity allocations<sup>8</sup>.

As an example of equity criterion, consider equation (2) for the case where the characteristic function is defined assuming that population is the relevant criterion. Note that this definition is based on the basic voting theory principle “one man, one vote”. More often than not, population is mentioned as a basis for emission permits allocations and this base is consistent with the egalitarian criterion that induces a proportional allocation to population. Our framework expands this criterion. Since the concept we use (the Shapley value) distribute emission permits between countries in a way that satisfied the weighted power majority of countries, we can argue that this concept is characterized by what Rose and Stevens called the “consensus equity”. In other words, at least in the idealized context of an analytic framework, the allocation rule we propose make the international bargaining process fair and promote a solution that is politically stable. Of course, since countries with large population have bigger bargaining power than others, the Shapley value is also tied to the egalitarian criterion.

Hence, the Shapley value can address the distribution of initial endowments between countries in a manner that induced the fairness of the international negotiation process. But the negotiations were held not only between Heads of Delegation in Kyoto, but also between Heads of State from their capitols. In fact, the discussions on the flexible mechanisms could not be concluded by the time the Conference ended. It is clear that lobbies opposed to dealing with the climate change have thoroughly worked the political system.

We propose three co-operative game concepts to capture the bargaining process within countries. The three Shapley-based CS (cooperative solution) values we propose distribute emission permits satisfying the weighted power of each regions, or firms. In that sense, these values are also characterized by consensus equity. The difference between these three allocation rules come from the outcome that might arise. Actually, the outcome of the first allocation rule  $\Psi_1$  (the null threat and egalitarian principle in section 2.1) is characterized at the domestic level by

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<sup>8</sup> For a discussion of the efficiency of the Shapley value in making allocations, see Eatwell, Milgate and Newman (1989), p. 24 and p. 213.

the egalitarian criterion when the outcome of the second one  $\Psi_2$  ( the strong threat and the quotient game lobbying principle in section 2.2) depends exclusively on the bargaining power of each region we can consider.

The third allocation rule  $\Psi_3$  (the subsidiarity principle in section 2.3) is the more appropriate for the introduction of flexible mechanisms as part of the control of the buildup of global warming gases in the atmosphere. First of all, it makes the international bargaining process fair and also promotes solution that is politically stable at the international level. Secondly, it makes the domestic bargaining process (and the bargaining process at each level : Federal government, State governments and local government, etc.) fair and promote also a solution that is politically stable. Finally and most importantly, the allocation rule based on the subsidiarity principle allows the use of different types of control mechanism at different level of negotiation process. In other words, subject to the agreement reached at the international level, each national program can be based on an efficient and fair allocation rule and subject to the agreement reached at the national level, each local program can also be based on a rule that addresses the requirement of efficiency and fairness.

The possibility for countries to form blocks that will meet the aggregate emission level of the countries forming the block motivates this co-operative game theory background . In this framework, perhaps surprisingly, the notion of fairness and power are very closed. The key concept of these allocation rules is that the outcome an individual can obtain depends on her bargaining power. In general, firms have more influence at the regional level than at the country level, and even less so at the international level. If the relative power of large to small producers at regional and country levels is lower than their relative power at the international level, then small firms will likely prefer scenario 2.2 to 2.3. By the same reasoning, large firms will prefer 2.3 to 2.2, and certainly, 2.1 is their least preferable scenario.

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