

Working Paper 258

Toward a Framework for Implementation of Climate Change Treaty through Self-enforcing Mechanisms

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January 2012



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Abstract

Global warming caused by accumulation of emissions of greenhouse gases (GHGs) is a public bad, addressing which requires collective action by all the countries of the world. Under the United Nations Convention on Climate Change (UNFCCC), most countries have negotiated the Kyoto Protocol for GHG emissions control to stabilize climate change. Several issues about the Protocol remain unresolved -- first, most of the significant countries are required to take a decision on whether or not to sign such a protocol, which has large-scale implications for their energy and industrial sectors and economic well-being; second, climate change mitigation is a public good entailing that all the countries would stand to gain due to mitigation action taken by a sub-group of one or more countries; and third, there exists no supra-national authority to enforce such a protocol for the individual sovereign nations. Thus, commitment to cooperate on an international agreement on climate change control remains tenuous. Formally, such a cooperative model is likely to be unstable. The paper discusses the pros and cons of the already proposed international cooperative mechanisms toward climate change mitigation and highlights the problem of information revelation, particularly related to the abatement issues. In this context, it attempts to outline a structure of a self-enforcing burden sharing mechanism for climate change mitigation in an incomplete information framework. The mechanism is an adoption of the well-known Vickrey-Clarke-Groves mechanism, widely used in mechanism design theory.

JEL Classifications: D02, D71, Q54, Q58.

Keywords: *Climate change negotiations; cooperative games; stable coalitions; self-enforcing mechanism.*

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equation such as (2) for each country i yields the socially desirable pollution vector, which we denote by $p^S = (p_1^S, p_2^S, \dots, p_n^S)$. As implied by (2), each country chooses its pollution so as to equate its marginal benefit from pollution to the aggregate marginal cost for all the n countries put together.

However, socially desirable outcomes such as those characterised by the condition in eq. (2) are normative equilibria that are almost non-existent in real economies, thus making it near impossible to enforce any form of global co-operation in a basic static setting such as the one described here. This is because any strategy to co-operate, conditional on co-operation by other countries, is never rewarded. That renders it irrational for a country to co-operate. This motivates the analysis of non-co-operative outcomes in the international climate change game (Finus, 2003).

4.2. Non-co-operative behaviour and climate change

Climate change can be visualised as a special case of the Prisoner's Dilemma game, wherein each country strategically decides on how much to pollute, given the pollution by other countries. That is, the maximisation behaviour of a single country takes as given the emissions of the remaining countries. The Nash equilibrium that emerges can be referred to as the status quo, before an international environmental agreement (IEA) is signed (Finus, 2003).

Again, with p_i representing the emissions of country i , the net utility/benefit, u_i , for the i th country is expressed as

$$u_i = b_i(p_i) - d_i(\sum_{j \in N} p_j), \quad (3)$$

where functions $b_i(\cdot)$ and $d_i(\cdot)$ are as defined earlier.

The Nash non-co-operative equilibrium is worked out by solving

$$\max_{p_i} u_i(p_1, p_2, \dots, p_i, \dots, p_n) \quad \forall i \in N, \quad (4)$$

that yields the first-order condition to be

$$b'_i(p_i) = d'_i(\sum_{j \in N} p_j). \quad (5)$$

This implies that the marginal benefit of pollution is equated to own marginal cost by each country i . Implicitly solving (5) derives the non-co-operative level of pollution generated by the i th country as a function of pollution levels of all the remaining $(n - 1)$ countries, or $p_i = f_i(p_{-i})$. This constitutes the best-response function of the i th country, or its best reply, given the emissions of the remaining countries. We would thus have n such functions, one for each country in the set N . Notably, the slope of the best response function will be derived as

$$\frac{dp_i}{dp_{j \neq i}} = \frac{d_i''}{b_i'' - d_i''} < 0,$$

in view of $b_i'' < 0$, $d_i'' > 0$. Thus, as expected, the best response to an increase in the emissions by any country j is that country i will be induced to reduce its emissions. The simultaneous solution of these best response functions will yield the vector of pollution levels $p^{NC} = (p_1^{NC}, p_2^{NC}, \dots, p_n^{NC})$ at the non-co-operative Nash equilibrium, which are lower than the ‘no-abatement equilibrium’ that assumes a complete disregard for any damage/disutility from pollution, p^{Max} . That is, the vector p^{Max} results as the $\arg \max u_i = b_i(p_i)$, by all i .

Nevertheless, aggregate emissions (here) are higher than what is socially desirable, since no country recognises the damages that its own emissions would inflict on other countries. In this sense, Nash non-co-operative outcomes are considered as sub-optimal. The other assumptions that form the basis for a non-co-operative game are complete information about each country’s benefits and costs and the absence of a central authority that could allocate and enforce pollution rights on countries. In real economies, both these assumptions do not hold. First, typically countries of the world do communicate and take co-operative decisions on enforceable agreements, such as the Montreal Protocol (to deal with ozone depleting substances) and the Kyoto Protocol (to tackle the problem of global warming and climate change due to GHGs). Second, information asymmetry in the form of absence of information by participants to the treaty about each other’s benefits and costs of pollution may lead to incentives to misreport their preferences and/or abatement costs for pollution cleanup. In respect of the first, the analysis in the paper has been extended to consider coalition formation to incorporate the role of binding commitments as part of an international climate treaty, such as the Kyoto Protocol. This is included in Section 4.3. The second of these concerns, namely, those relating to information asymmetry that render such co-operation difficult, constitute the centrepiece our paper and is discussed in Section 5 of the paper.

4.3. International coalitional games of climate change

Analytical models of coalitional games have been utilised in the context of climate change under both co-operative and non-co-operative game theoretic framework. Typically, a co-operation-based coalitional model is distinguished from the one that is based on non-co-operation, first, by its focus on what the group of countries can achieve in terms of emissions abatement as part of a binding agreement than on what the individual players can do and second, by the fact that co-operative behaviour ignores how the group of countries/players in the coalition function internally. Alternatively, when the possibility of coalition formation is modelled as a non-co-operative game, one must specify how the coalitions form and how the individual member countries choose joint actions (Osborne and Rubinstein, 1994). Typically, as will be explained below, while co-operation based coalitions derive from the aggregate

worth of a coalition (or what the aggregate payoffs for the coalition are), those from non-co-operative behaviour obtain from individual payoffs. Further, in case of co-operative climate regimes, the worth of a climate coalition is based on the actions of those inside the coalition wherein these actions are distinguishable from those who are outside it. In comparison, the value or the payoffs of the individual non-co-operation based climate blocs are drawn from the same guiding rules or principles. In addition, while co-operation based coalitions rely on the concept of a Core (defined below), the non-co-operative games of coalition formation function on the premise of internal and external stability. A more formal exposition of these aspects is presented below.

4.3.1. Co-operation and concept of Core

If N_1 denotes a subset of countries forming a climate coalition or climate bloc and N_2 is the set of countries that lie outside the climate bloc such that $N_1 + N_2 = N$, then the worth of the coalition N_1 can be defined by the characteristic function, w , which is

$$w(N_1) = \sum_{i \in N_1} u_i(p_{N_1}, p_{N_2}), \quad (6)$$

with the emissions vector p_{N_2} following from some assumed action taken by the countries outside of the climate coalition, while N_1 , N_2 and p_{N_1} are derived by solving the maximisation problem for the countries in the climate bloc; that is,

$$\max_{p_{N_1}} \sum_{i \in N_1} u_i(p_{N_1}, p_{N_2}). \quad (7)$$

The expression in (6) means that the worth of the coalition is the total payoff that is available for division amongst the members of the climate bloc N_1 .

The notion of stability of a coalition in this case is embodied in the concept of the ‘‘Core’’. The idea of the Core is analogous to that of the Nash equilibrium of a non-co-operative game, that is, an outcome is stable if no feasible group-deviation is profitable or no sub-coalition can deviate and do better for its members. In general, for an n – player coalitional game with transferable utility, defined by a set of players, N , and a characteristic function, w , the Core is defined as $C(N, w)$ such that

$$C(N, w) = \{\pi \in R^n: \sum_{i \in N} \pi_i = w(N) \text{ and } \sum_{i \in N_1} \pi_i \geq w(N_1) \forall N_1 \subseteq N\}, \quad (8)$$

where $\pi = (\pi_1, \pi_2, \dots, \pi_n)$ is an n – dimensional imputation. An imputation is defined as an ‘‘efficient’’ and ‘‘individually rational’’ distribution of the payoff of the grand coalition, a single coalition with all the n players as members.⁵ That is, the Core is the

⁵ Efficiency implies that the aggregate payoff exactly distributes the total value, or $\sum_{i \in N} \pi_i = w(N)$, and individual rationality entails that individually the distributed payoff is at least as high as what a player could obtain on its own, or, $\pi_i \geq w(\{i\}) \forall i \in N$.

set of imputations in which no coalition has a value greater than the sum of its members' payoffs. Therefore, no coalition has the incentive to leave the grand coalition and receive a larger payoff (Osborne and Rubinstein, 1994; Wood, 2010).

In the specific circumstance of a global climate change treaty, one shall be concerned with the grand coalition (N) implementing the socially desirable emissions vector. Accordingly, if $\pi^S = (\pi_1^S, \pi_2^S, \dots, \pi_n^S)$ defines the imputation at the socially desirable emissions vector, p^S , and t_i is the transfer such that $\sum_{i \in N_1} t_i = 0$, and $\pi_i^* = \pi_i^S + t_i$, then an imputation $\pi^* = (\pi_1^*, \pi_2^*, \dots, \pi_n^*)$ lies in the Core if $\sum_{i \in N_1} \pi_i^* \geq w(N_1) \forall N_1 \subseteq N$ (Finus, 2003).

Accordingly, the focus of analysis in Chander and Tulkens (1997) is on the γ -core. They characterise the co-operative game where a subset N_1 of countries denotes the climate coalition, which maximises its collective benefit, while N_2 is the set of countries that lie outside the climate bloc and act non-co-operatively. Then, following the notion of payoff described in (6), the payoff or utility of the climate bloc will be:

$$w_\gamma(N_1) = \sum_{i \in N_1} u_i(p_{N_1}, p_{N_2}), \quad (9)$$

where p_{N_1} and p_{N_2} are the emissions of the climate bloc and sum of emissions of countries outside the bloc respectively. The Core of the associated game will be the set of possible payoff vectors for the countries in the grand coalition where no coalition will benefit if the grand coalition dissolves into singletons (or individual countries) when any coalition or individual country breaks away from it. Thus, all countries are singletons and maximise their individual payoffs, as in the Nash equilibrium. The payoff of a country i depends upon its emissions as well as the transfers t_i received by it such that $\sum_{i \in N_1} t_i = 0$. Thus,

$$\pi_i = b_i(p_i) - d_i(\sum_{j \in N} p_j) + t_i. \quad (10)$$

It is shown by Chander and Tulkens (1997) that the γ -core is non-empty if the transfers are chosen such that

$$t_i = b_i(p_i^{NC}) - b_i(p_i^S) - \frac{d_i(\sum_{j \in N} p_j^S)}{\sum_{k \in N} d_k(\sum_{j \in N} p_j^S)} \cdot [\sum_{k \in N} b_k(p_k^{NC}) - \sum_{k \in N} b_k(p_k^S)]. \quad (11)$$

with superscripts NC and S denoting the non-co-operative and socially optimal outcomes respectively, the first term in the right hand side of (11) is payment to be received by a country as compensation for the loss of utility that it will suffer in moving from the Nash equilibrium to the social optimum. The second term is the payment made by each country in proportion to the fraction of marginal damages in it to the total marginal damages in all the countries covering the total decrease of benefits included in the square brackets (due to a move from the social optimum to the non-co-operative outcome). Thus, according to (11), a country that gains more from emissions reduction

in the form of reduced marginal damages also bears a larger opportunity cost of co-operation.

The concept of a Core such as the one described above is criticised in at least two significant respects (Finus, 2003). First, the Core carries a normative notion as it focuses on the first-best or the most efficient outcomes. Thus, it does not explain real world phenomena such as formation of sub-optimal coalitions or climate blocs such as those that have emerged lately, namely the emerging economies of BRIC countries together with the US, small island states etc. at the Copenhagen Summit. Second, while the transfer scheme is useful in the context of a heterogeneous set of countries, the transfer formula provides an incentive to countries to misreport their abatement costs and environmental preferences. Since the payments depend on the fraction $\frac{d'_i(\sum_{j \in N} p_j^S)}{\sum_{k \in N} d'_k(\sum_{j \in N} p_j^S)}$, countries may have the incentive to bias their estimation downward, while with the receipts depending on the loss of benefits, captured by the difference $b_i(p_i^{NC}) - b_i(p_i^S)$, countries might tend to overstate this loss or utility to receive higher compensation. This leads us to seek out alternative forms of coalitions based on non-co-operative behaviour.

4.3.2. Coalition formation as a non-co-operative game

In comparison with the above, if one assumes the emergence of several coalitions, say M number of coalitions, with the structure $C = (C_1, C_2, \dots, C_K, \dots, C_M)$, then the value function of country i that belongs to a coalition, say C_K , can be expressed as

$$v_i(C_K, C) = u_i(p^{NCC}) + t_i, \quad (12)$$

where $p^{NCC} = (p_1^{NCC}, p_2^{NCC}, \dots, p_K^{NCC}, \dots, p_M^{NCC})$ is the equilibrium vector of pollutants emitted by each coalition $C_K \in C$ (with NCC denoting the non-co-operative coalitions outcome) by maximising the total payoff of countries belonging to the coalition, that is,

$$\max_{p_K} \sum_{i \in C_K} u_i(p_K, p_{-K}) \quad (13)$$

and t_i is the transfer paid or received by country i based on a decided transfer mechanism. Notably, the emissions vector p_{-K} follows from all coalitions outside of C_K maximizing their individual payoffs.

Non-co-operation based coalitions pre-suppose stability as put forward by d'Asperemont et.al (1983) implying both internal and external stability of the cartel. These concepts of stability underlie the works of Carraro and Siniscalco (1991, 1993), Barrett (1994, 1997), Carraro (2000) and Finus (2001), which rely on either Nash-Cournot (simultaneous move) or Stackelberg (sequential move) behaviour by countries who participate in the international climate treaty versus those who do not participate.⁶

⁶ More precisely, a simultaneous move game assumes that the choice of emissions by the participants and non-participants is made concurrently in time; the sequential game is premised on a sequential choice

Internal stability entails that no member or participant of the coalition has the incentive to leave the coalition to become a non-member while external stability implies that no non-participant finds it profitable to become a member of the coalition.

More formally, with payoff of coalition C_K^* defined as above, where a participant $i \in C_K^*$ and a non-participant $j \notin C_K^*$, and with the coalition structure given by $C = (C_K^*, 1, 1, \dots, 1)$, where C_K^* denotes the coalition of countries, while other countries do not form a coalition but remain singletons, then stability is characterised by the following:

Internal stability: $v_i(C_K^*: C_K^*, 1, 1, \dots, 1) - v_i(i: C_K^* - 1, 1, 1, \dots, 1) \geq 0 \forall i \in C_K^*$ that implies that there is no incentive for a member country to leave the climate coalition.

External stability: $v_j(j: C_K^*, 1, 1, \dots, 1) - v_j(C_K^* + j: C_K^* + j, 1, 1, \dots, 1) \geq 0 \forall j \notin C_K^*$, which means that there is no incentive for a non-member country to join the climate coalition.

Finus (2003) evaluates the premise of internal and external stability and claims that the internal stability of a coalition derives from the notion of profitability for all the participants as compared to the status quo and of joint welfare maximisation of the climate coalition. However, in the face of heterogeneity of countries and need for operating side payments (as transfers), there is less support for the premise of joint welfare maximisation through co-operation amongst countries of the world. Furthermore, the notion of self-enforcing international climate treaties rests on the premise of weak punishment in that as a member country leaves the coalition, the others merely hang on together and re-optimize their strategies. This is indeed corroborated by real world experience of the limited scope for punishment (as compared to the Core) and is likely to reduce the effectiveness of climate change treaties. Finally, the notion of stability rests on the assumption of complete information. In reality, the problems of information asymmetry between countries, about costs of climate abatement or environmental preferences, persist. This makes it necessary to turn attention to self-enforcing mechanisms for climate change mitigation that would explicitly incorporate such information constraints. In this sense, mechanisms that address information constraints may yield pollution outcomes that are worse than those under full co-operation as these tend to be second- or third-best, to say the least. The design of self-enforcing climate change in the face of information issues constitutes the focus of discussion in the next section.

of emissions such that the participants are the Stackelberg leader and non-participants are Stackelberg followers.

5. Self-enforcing framework to implement social optimum: a mechanism design approach

We reconsider the global emissions framework as introduced in Section 4. As has been discussed, the sharing of burden/costs of lowering GHGs to mitigate global warming is a typical case of public goods provision, and as conjectured by Samuelson (1954), there exists no resource allocation mechanism that can ensure a fully efficient level of this provision. There is little incentive for individual countries to take account of the global pollution created by gross emissions by all countries. The key parameters that affect an individual country's decision regarding emissions are the direct effect of the emission reduction on its cost of production (or emissions abatement) or utility/ benefits. These parameters address the aggregate costs incurred to reduce the negative impact of emissions. Analysis of these types of costs is not rare in environmental economics, especially in the context of public goods provision. A common example is the costs associated with cleaning up an oil spill. Henceforth, we focus only on the emissions abatement costs and call the parameter the "clean-up cost" of emissions.

Clearly, the clean-up cost of a country depends on the technologies available to it, cost-effectiveness etc. Therefore, it is understandable that information regarding the clean-up cost of a country may not be readily available to other countries, that is, the clean-up cost of a country is very much its "private information" (we will also call it "type"). As already pointed out in Section 4, when each country pursues its own welfare maximisation, the resulting outcome deviates from the socially optimum outcome. A natural question that arises is whether it is possible to co-ordinate the actions of all countries such that they not only consider their individual clean-up costs, but also endogenise the "public bad" nature of emissions into their decision-making. If we believe that there is an international regulatory authority to enforce such a social optimum, we must also assume that the authority has adequate information regarding the clean-up costs of all the countries needed to achieve emissions reduction in an efficient manner. This is because the authority must minimise the total cost inflicted on the global society by the aggregate emissions of all countries. This total cost must internalise the cost on the global society from emissions *apart from* the clean-up cost of individual countries.. The main hurdle the regulatory authority faces is lack of information about clean-up costs of individual countries. The only "non-strategic" approach could be just to ask the countries to report their clean-up costs. But, there are enough reasons to believe that the countries *will not report truthfully!*

To put it intuitively, since the clean-up costs of all the countries are unknown to the authority and is not directly verifiable, each country would try and strategise its reporting in its favour.⁷ In other words, if asked to report its clean-up cost, a country

⁷ Each country would have the incentive to either misreport (understate) its willingness to pay or overstate its costs of pollution abatement, so as to reduce its own share of aggregate clean-up burden.

will have a wide range of possible values to report from. It is very likely that if the country reports an incorrect value for its clean-up cost, the country is better off!

It is, therefore, not sufficient to constitute a regulatory authority (e.g. supra-national institution) even with consensus among all the countries. Although countries agree on tackling the global pollution emerging from their individual actions, enforcement remains difficult (to say the least!) as each country finds it beneficial to be strategic and report “not truthfully”.

The entire scenario demands a solution concept, which can *strategically* enforce or implement the socially optimal outcome, that is, can eke out the private information from the countries by providing appropriate incentives for doing so and by proving to be adequately adverse for not doing so! This requires use of tools from game theory with a framework leading to an objective outcome for every possible parametric configuration or type-vector of countries (characterised by clean-up costs, pollution damages and such like). We also require this entire set-up to be such that it works with no external assumptions, but with a built-in process. This is a reasonable demand placed on the mechanism, as the existence of a supra-national authority is both difficult to achieve and entails a lot of “not so much economic” factors. We would rather abstain from this difficulty and would be happier with the framework being self-enforcing. Thus, ultimately we arrive in the domain of what is called a *Mechanism Design* problem! Mechanism design provides a framework for the analysis of allocation mechanisms (for example, a public good such as climate change mitigation) with specific focus on problems associated with incentives and private information. In our specific context of climate change mitigation, the allocation mechanism will be proposed to be adopted at the international level and ensure compliance that will be driven by the compatibility of allocation rules with individual countries’ self-interested goals.

In the next sub-section, we introduce the formal model. Thereafter, we demonstrate the divergence between the social and private optima, given the information problems outlined above. Lastly, we provide a simple self-enforcing mechanism that implements the social optimum while ensuring that countries report truthfully without overstating clean-up cost or understating emissions.

5.1. The Model

We closely follow the set-up introduced in the last section. To formalise the above structure as a tractable model, we make a couple of assumptions. We assume that there is only one homogeneous form of pollution arising out of emissions and we assume that it is possible to put a value on the environmental damage from the aggregate level of emissions. Like earlier, let $N = (1, 2, \dots, n)$ denote the set of all countries. Also, let $E = (P_1, P_2, \dots, P_n)$ denote the emissions vector that specifies the emissions levels by all the countries in N . Let D be the social damage or social cost function that captures the global cost inflicted by the emissions by all the countries. Thus, $D(P)$ denotes the

total damage value, where P is the total or aggregate worldwide emissions, i.e. $P = \sum_{i=1}^n P_i$. It is assumed that $D'(P) > 0$ and $D''(P) > 0$. These assumptions regarding the cost functions are standard in economics literature. We note that D denotes the *overall* damage to the world. Thus, even though countries do vary in terms of being affected by climate change, function D captures the “public bad” aspect of it, namely, the cost borne by the entire world.⁸

Let $C(P_i, \theta_i)$ denote the clean-up cost incurred by the i th country, where P_i is the emissions by the i th country and θ_i is a parameter indicating clean-up technologies available with the i th country. Naturally, the cost incurred to wipe out the negative effects of emissions depends on (a) the amount of emissions (P_i) and (b) the technologies (including advancements and innovations which are mainly dynamic in nature) or equipment available and favourable environment (θ_i). Clearly, θ_i captures all the information that is private in nature and unknown to all except the i th country. We also assume that $\partial C / \partial P_i < 0$ and $\partial^2 C / \partial P_i^2 > 0$. The first assumption depicts that the clean-up cost rises as the amount of pollution falls. The second assumption implies that the marginal clean-up cost rises as the amount of emissions by a country rises. We reiterate that both the determining factors, P_i and θ_i , are known to the i th country. More concretely, countries know their respective clean-up cost functions.⁹

5.2. Social optimum and private optimum

Consider a laissez-faire economy with clean-up cost function $C(., \theta_i)$. With no regulation on its emissions, the country chooses an emissions level P_i that minimises its cost, i.e. the clean-up cost $C(P_i, \theta_i)$. This is given by simple optimisation condition:

$$\frac{\partial C}{\partial P_i} = 0 \Rightarrow C(\bar{P}_i, \theta_i) = 0 \quad (10)$$

Thus \bar{P}_i is the optimal level of emissions that the country chooses to emit when there is no regulation.¹⁰ We now characterise the social optimum in this framework. To reach a socially optimal (or efficient) level of emissions, we need to minimise the total cost inflicted by all the countries put together, i.e.

$$\underset{P_i}{\text{Min}} [D(P(\theta)) + \sum_{i=1}^n C(P_i(\theta), \theta_i)] \quad \text{subject to } \sum_{i=1}^n P_i(\theta) = P, \text{ for all } \theta. \quad (11)$$

⁸ That is, the cross-country differences in pollution damages are not ruled out.

⁹ Notably, clean up costs may be beset with uncertainty. However, the paper abstracts from issues of uncertainty in clean-up costs and instead focuses attention only on the issues of asymmetry of information of these costs across countries.

¹⁰ This is analogous to the unbounded emissions characterised in the last section, but now by taking into account information asymmetry on clean-up costs.

Clearly, the solution to (11) requires finding out an emissions vector \bar{P}_1 such that it is obtained by solving the following expression:

$$\left[\frac{\partial D(P)}{\partial P_i} \right] + \frac{\partial C}{\partial P_i} = 0 \Rightarrow \frac{\partial C}{\partial P_i} = - \frac{\partial D(P)}{\partial P_i} \quad (12)$$

Since in (12), $D'(P) > 0$ and $\frac{\partial C}{\partial P_i} < 0$ when evaluated at \bar{P}_1 , it must be that $\bar{P}_1(\Theta) > \bar{P}_1(\Theta)$. This shows that private optimal emissions are higher than the socially optimal level. This is very much in conformity to what we have argued so far and captures the effect of emissions as a global public bad while computing the global socially optimal outcome.

While we have justified our requirement for a self-enforcing framework that elicits truth telling from the respective countries and establishes a socially optimal outcome, we have not said much about the economic frameworks that will make it achievable. Next, we give a brief overview of such frameworks or Mechanism Design theory.

5.3. The mechanism design problem

Implementation theory deals with group decision-making processes under various information structures. The objective of this theory is to structure the strategic interactions of the agents in a group so that their actions lead to a socially desirable outcome in each “state of the world”, which in our case will take the form of optimal GHG emissions abatement. The group’s collective objectives are specified by a social choice rule that selects a set of alternatives from the available set in every state of the world. A classic example is the one of building a public good or project by a public authority. The authority needs to compare its cost to its social benefit. For this, the authority needs to know all agents’ valuations for the project. But these valuations are private information of the agents and unknown to the public authority. Implementation theory attempts to design a game-form such that in every state, the equilibrium actions of the agents, according to a pre-specified equilibrium notion, lead to a socially desirable outcome in that state, that is, they belong to the image-set of the Social Choice Correspondence (SCC) in that state. Information available to the agents but unknown to the planner will affect the socially desirable outcome. The formulation of the problem, therefore, must use game-theoretic solution concepts that are appropriate for agents’ behaviour and consistent with the informational assumptions. The literature on implementation considers a wide range of equilibrium notions. In the “complete information models” (such as those discussed in Section 4), it is assumed that all agents know the state while the mechanism designer/ regulator does not. A natural notion of equilibrium in this context is Nash equilibrium (Maskin (1999)). Other notions that are consistent with this information setting and that have been studied include the iterated

elimination of weakly un-dominated strategies (Moulin (1979)), sub-game perfect Nash equilibrium and various other Nash equilibrium refinements.¹¹

In a private information setting, each agent has private information about his/her type and a state is the set of types of all agents. The mechanism designer does not have information regarding the state. Further, an agent only knows its own type but is unaware of types of other agents. In this setting, solution concepts such as Nash implementation or iterated elimination of dominant strategies are inapplicable. This is because an agent is unable to predict the actions of the other agents regarding the elimination of strategies.

A natural notion (amongst others) in this setting is *dominant strategies*. An agent never loses if it uses a dominant strategy at a particular state without thinking about strategies chosen by others.¹² This solution concept is also quite robust with respect to the information environment amongst the countries/players. In the current setting, we also aim to devise a mechanism, which can implement (in dominant strategies, that is, using dominant strategies at every possible state) socially optimal outcomes in the global emissions game. The following discussion focuses on one such mechanism.

5.4. A self-enforcing mechanism

We consider a setting where countries can communicate with the regulator the optimal outcome in the global emissions game (existence of a regulator may be virtual here, as it is not essential to have a real institution that acts as a regulator or planner here) but cannot with one another. We consider schemes where the countries have been asked to report their types in terms of their emissions abatement costs, that is, θ_i s. Suppose the scheme also involves a *tax payment* to be made by each country, based on the vector of announced types ($\widehat{\theta} = (\widehat{\theta}_1, \dots, \widehat{\theta}_n)$) and the emission level chosen by that country. The aim is to design the scheme in such a manner that each country finds it *not beneficial* for her to announce a wrong type! Thus, the transfer payment function for the i th country would depend on the announced type $\widehat{\theta}_i$, announcements by the other countries $\widehat{\theta}_{-i}$, and emission level by the country i , i.e. P_i .

We describe the scheme again: countries are asked to report their respective types, θ_i s. They are also informed beforehand (that is, before they announce their types) that based on their announcement vector $\widehat{\theta}$, each country would pay a tax. We note that the tax payment made by a country *may not* be positive. The novelty of this piece of research

¹¹ Since every agent knows the types of the other agents as well, they would conjecture the possible actions taken by the other agents. Natural notions of equilibrium in this set up would arise from this pattern of rational behavior by all agents and thus iterated elimination of weak strategies or sub-game perfect equilibrium (in a more dynamic setting) are appropriate in this case. Nash equilibrium of course remains an important equilibrium concept, given its self-sufficient property by definition.

¹² If a mechanism implements a social choice function in dominant strategies, then the direct mechanism is *dominant strategy incentive compatible*.

would lie in cleverly designing the tax payment function such that each country is incentivised to tell/reveal the truth about its type.

First, we define the social choice function as the rule that maps into optimal (or *efficient*) levels of emissions for a type vector. This implies that, given that the set of countries' true types is θ , allowable emissions are set at $\bar{P}_i(\theta)$, for all $i \in N$. If the announced type vector is $\hat{\theta}$, the outcome is $\bar{P}_i(\hat{\theta})$. But this does not complete the description of the social choice function, as it needs to also specify the rules for the tax payments. We note that the trick lies in constructing the tax functions. This is because tax is the only channel through which the net payoffs of countries are adversely affected by higher emissions. The other part of the net payoff is the clean-up cost, which pushes the country to choose away from the socially optimal outcome.

In particular, the cost function of an individual country i , whose true type is θ_i but announces $\hat{\theta}_i$, (and other countries are announcing θ_{-i}) is $C(\bar{P}_i, \theta_i) + T_i(\bar{P}_i, \hat{\theta}_i, \theta_{-i})$, where \bar{P}_i is the *efficient* emission level chosen by the country i . If a mechanism enforces "truth-telling" by the countries, then we must have:

$$C(\bar{P}_i(\hat{\theta}_i, \theta_{-i}), \theta_i) + T_i(\bar{P}_i(\hat{\theta}_i, \theta_{-i}), \hat{\theta}_i, \theta_{-i}) > C(\bar{P}_i(\theta), \theta_i) + T_i(\bar{P}_i(\theta), \theta_i, \theta_{-i})$$

for all $i \in N$

The left hand side of the inequality is the clean-up cost of country i and the tax paid when the true type of the country is θ_i and the announced type is $\hat{\theta}_i$. Thus, this is the cost of the country while lying. The right hand side is the cost when the country is telling the truth. Naturally, telling the truth becomes the dominant strategy if the above inequality holds for any P_i and any possible announcement vector by the other countries θ_{-i} .

This is a case where an adaptation of the classic Vickrey-Clarke-Groves mechanism (VCG) would be applicable to elicit truth telling as the dominant strategy for each country (Clarke (1971), Groves (1973)). We state the main result in the next proposition:

Proposition: If \bar{P}_i be an efficient emission function and, for each country i , there exists a transfer function $T_i(\theta) = A_i(\theta_{-i}) + \sum_{j \neq i} C(\bar{P}_j(\theta_i, \theta_{-i}), \theta_j) + D(\bar{P}(\theta))$, then (\bar{P}, T_i) is dominant strategy incentive compatible.

Proof: The mechanism is as follows - the countries announce their types, i.e. θ_i s and the mechanism yields the levels of emission allotted to each country (given by \bar{P}_i) and taxes (given by T_i). We prove the proposition by the method of contradiction. Let (\bar{P}, T_i) be not dominant strategy incentive compatible. Thus, there exists $i, \theta, \hat{\theta}_i$ such that

$$C(\bar{P}_i(\theta), \theta_i) + A_i(\theta_{-i}) + \sum_{j \neq i} C(\bar{P}_j(\theta_i, \theta_{-i}), \theta_j) + D(\bar{P}(\theta)) >$$

$$C(\bar{P}_i(\hat{\theta}_i, \theta_{-i}), \theta_i) + A_i(\theta_{-i}) + \sum_{j \neq i} C(\bar{P}_j(\hat{\theta}_i, \theta_{-i}), \theta_j) + D(\bar{P}(\hat{\theta}_i, \theta_{-i})).$$

Or,

$$\sum_{i \in N} C(\bar{P}_i(\theta), \theta_i) + D(\bar{P}(\theta)) > \sum_{i \in N} C(\bar{P}_i(\hat{\theta}_i, \theta_{-i}), \theta_i) + D(\bar{P}(\hat{\theta}_i, \theta_{-i}))$$

But this violates the efficiency of \bar{P} !

Hence, we prove that the direct revelation mechanism implements the efficient social choice rule in dominant strategies. This is an application of VCG mechanism. This mechanism has been used for many practical purposes including combinatorial auctions, replica placements etc.

5.5. The pros and cons: research ahead

The tax function introduced in the last section induces each country to tell *the truth*, irrespective of the announcements made by other countries. Thus, it is a *dominant strategy* for the country to tell the truth regarding the type θ_i . The underlying principle is the same as the VCG mechanism, famous in Mechanism Design theory. We observe that the tax payments by an individual country depend on the social cost of gross pollution as well as on the (clean-up) costs inflicted on *other* countries from *optimal* emissions calculated at the announced cost-type vector. It will be interesting to simulate numerically the model with an arbitrary data set for a group of countries and to show how it works. However, we wish to address this problem in our future research.

The only negative aspect of the VCG model is the assumption made by Clarke (1971) and Groves (1973) that there exist no income effects on the demand for better environment quality (in the context of this research). In other words, the VCG mechanism elicits truth telling about clean-up costs as a dominant strategy and the aggregate level clean-up of GHG emissions is at the socially desirable level when the utility function is quasi-linear. As part of our future research, one needs to seek out alternative adaptations of the VCG mechanism that would apply to a broader class of utility functions. Further, the transfers are not necessarily balanced, that is, the aggregate tax revenue may not add up to the aggregate costs of emissions abatement. This motivates a research question - characterisation of the tax functions in the model discussed above. It will also be interesting to find out what could be the practical implications of these tax payments. Most importantly, however, the framework, in principle, works *without the physical presence of a supra national authority*. Thus, a group of countries, with honest intention (at least in the negotiations round!) conforming to the mechanism designed above, must end up implementing the *socially optimum outcome*! Also, this is true for *any* number of countries and irrespective of the

types of countries. The solution concept here is also quite robust, because the optimal strategies of all countries are *dominant* strategies, which are independent of a country's knowledge regarding the types (e.g. technologies available) of other countries. Thus, we overcome the difficulties faced in other solution concepts alluded to earlier.

References

- Barret, S (1994). Self-Enforcing International Environmental Agreements. Oxford Economic Papers. 46, Pp 804-878.
- Barrett, S. (1997). Toward a Theory of International Environmental Cooperation. Carraro, C. and Siniscalco (Eds.). *New Directions in the Economic Theory of the Environment*. Cambridge University Press. Pp 239 – 280.
- BBC News (2010). Australia Shelves Key Emissions Trading Scheme. Available at <http://news.bbc.co.uk/2/hi/8645767.stm>
- Berset, S. and Blaser, V. (2010). The Copenhagen Global Climate Change Negotiations: Did they Fail? Department of Economics, Working Papers, Faculty Economics and Social Sciences, Universitat Friburgensis.
- Byrd-Hagel Resolution, 105th Congress, 1st Session <http://www.nationalcenter.org/KyotoSenate.html>.
- Carraro, C. (2000). Roads towards International Environmental Agreements. In Seibert, H. (Ed). *The Economics of International Environmental Problems*. Tübingen: Mohr Siebeck. Pp 169-202.
- Carraro, C, and Siniscalco, D. (1991). Strategies for International Protection of Environment. Working Paper 56:98. FEEM, Milan.
- Carraro and Siniscalco, D. (1993). Strategies for International Protection of Environment. *Journal of Public Economics*. 52. Pp 309-328.
- Chander, Prakash and Tulken, Henry (1997). The Core of the Economy with Multilateral Externalities. *International Journal of Game Theory*. 26(3). Pp 379-401.
- Clarke, E. 1971. Multipart Pricing of Public Goods. *Public Choice* 8 19–33.
- Climate Policy Post-Copenhagen: A Three-Level Strategy for Success, Policy Paper No. 6, German Advisory Council on Global Change, April 2010.
- Congress of the United States, Congressional Budget Office (2008). Policy Options for Reducing CO₂ Emissions. A CBO Study. February 2008. Pub. No. 2930.
- Coopes, A. (2009). Australia Delays Emissions Trading. Available at <http://news.theage.com.au/breaking-news-world/australia-delays-emissions-trading-20090504-asf5.html>
- D'Asperemont, C., A. Jacquemin, J.J. Gabszewicz and J.A. Weymark (1983), On the Stability of Collusive Price Leadership. *Canadian Journal of Economics*. 16. Pp 17-25.
- Dunne, P. (2009). Review of the Emissions Trading Scheme and Related Matters. Report of the Emissions Trading Scheme Review Committee. Forty-ninth Parliament. August 2009. Presented to the House of Representatives.

Ellerman, A. D. and Joskow, P.,L. (2008). The European Union's Emissions Trading System in Perspective. Policy brief prepared for the Pew Center on Global Climate Change. May 2008.

Finus, M. (2001). Game Theory and International Environmental Cooperation. Edward Elgar. Cheltenham, U.K.

Finus, M. (2003). Stability and Design of International Environmental Cooperation: the Case of Transboundary Pollution. Pp 82-158. In Folmer, H and Tietenberg, T (Eds). International Yearbook of Environmental and Resource Economics, 2003. Edward Elgar. Cheltenham, UK.

Freshfields Bruckhaus Deringer LLP (2010). Post-Copenhagen: Four Unavoidable Truths. January 2010.
<http://www.freshfields.com/publications/pdfs/2010/jan10/27416.pdf>

Garnaut Climate Change Review (2008). Interim Report to the Commonwealth, State and Territory Governments of Australia. February 2008.

Grainger, C., A. and Kolstad, C. D. (2009). Who Pays A Price on Carbon? NBER Working Paper Series. August 2009. Working Paper 15239.

Government of India (GoI) (2009). The Road to Copenhagen: India's Position on Climate Change Issues. Public Diplomacy Division, Ministry of External Affairs. Available at <http://www.meaindia.nic.in>.

Groves, T. 1973. Incentives in Teams. *Econometrica* 41 617–631.

Gurnsey, P. (2008). New Zealand Emissions Trading Scheme (NZ ETS). New Zealand Ministry for Environment. New Zealand Government. Available at http://www.icao.int/2008wacm/Docs/3_Gurnsey.pdf

Hasan, A. and Funston, L. (2008). The Introduction of Australia's Emissions Trading Scheme. Report prepared by the Australian Institute of Management VT. July 2008.

The Japan Times (2010). Emissions Trading Plan Shelved until after '13. Available at <http://search.japantimes.co.jp/cgi-bin/nb20101229a6.html>

Joanna I. Lewis (2007). China's Strategic Priorities in International Climate Change Negotiations. The Center for Strategic and International Studies and the Massachusetts Institute of Technology. The Washington Quarterly, Winter 2007-08, 31:1 pp. 155-174.

Jiang, N., Sharp, B. and Sheng, M. (2009). New Zealand's Emissions Trading Scheme. New Zealand economic papers, Apr 2009; v. 43, n. 1: p. 69-79. Available at [http://www.business.auckland.ac.nz/Portals/4/Research/ResearchCentresGroups/Energy%20centre/Sharp-NZEP-on-ETS%20\(2\).pdf](http://www.business.auckland.ac.nz/Portals/4/Research/ResearchCentresGroups/Energy%20centre/Sharp-NZEP-on-ETS%20(2).pdf)

Kruger, J. , Oates, W., E. and Pizer, W., A. (2007). Decentralization in the EU Emissions Trading Scheme and Lessons for Global Policy. Resources for the Future. February 2007. Discussion Paper 07-02.

Maleug, D., A. and Yates, A., J. (2009). Strategic Behaviour, Private Information, and Decentralization in the European Union Emissions Trading System. *Environmental and Resource Economics* (2009). Volume 43, Number 3, 413-432.

Maskin, E. (1999): "Nash Equilibrium and Welfare Optimality," *The Review of Economic Studies*, 66 (1), 23–38.

Metcalf, G., E. (2009). Designing a Carbon Tax to Reduce U.S. Greenhouse Gas Emissions. *Review of Environmental Economics and Policy*, volume 3, issue 1, winter 2009, pp. 63-83. Downloaded from <http://www.reep.oxfordjournals.org>.

Moulin, H. (1979): "Dominance Solvable Voting Schemes, *Econometrica*, 47, 1337–1351.

Nordhaus, W., D. (2007). To Tax or Not to Tax: Alternative Approaches to Slowing Global Warming . *Review of Environmental Economics and Policy*, volume 1, issue 1, winter 2007, pp. 26-44. Downloaded from [reep.oxfordjournals.org](http://www.reep.oxfordjournals.org).

Nordhaus, W., D. (2006). After Kyoto: Alternative Mechanisms to Control Global Warming. Study Prepared for American Economic Association Session on Global Warming and the Kyoto Protocol. January 2006.

Oberthur, S. and Kelly, C. R. (2008). EU Leadership in International Climate Policy: Achievements and Challenges. *The International Spectator*, Vol. 43, No. 3, September 2008, pp 35-50.

Osborne, M.J., and Rubinstein, A. (1994). *A Course in Game Theory*. The MIT Press.

Parker, L. (2010). Climate Change and the EU Emissions trading Scheme (ETS): Looking to 2020. CRS Report for Congress. Prepared for Members and Committees of Congress. Congressional Research Service. R41049. September 2010.

Ravindranath, N H and Sathaye, Jayant A (2002). *Climate Change and Developing Countries*, Kluwer Academic Publishers, Dordrecht, The Netherlands. 2002.

The Reality of Carbon Taxes in the 21st Century (2008). A Joint Project of the Environmental Tax Policy Institute and the Vermont Journal of Environmental Law. Western Newspaper Publishing Co. Available at [http://www.vermontlaw.edu/Documents/020309-carbonTaxPaper\(0\).pdf](http://www.vermontlaw.edu/Documents/020309-carbonTaxPaper(0).pdf)

Shrum, T. (2007). Greenhouse Gas Emissions: Policy and Economics. A Report Prepared for the Kansas Energy Council Goals Committee. June 2007.

Stavins, R. N. (2008). Addressing Climate Change with a Comprehensive US Cap-and-Trade System. *Oxford Review of Economic Policy*, Volume 24, Number 2, 2008. Pp. 298-321.

Stavins, R. N. (2003). Market-Based Environmental Policies: What Can We Learn from U.S. Experience (and Related Research)? *Resources for the Future*. August 2003. Discussion Paper 03-43.

Stavins, R. N. (2001). Experience with Market-Based Environmental Policy Instruments. Resources for the Future. November 2001. Discussion Paper 01-58.

Stern, Nicholas (2009). Action and Ambition for a Global Deal in Copenhagen. Centre for Climate Change Economics and Policy Grantham Research Institute for Climate Change and the Environment. In collaboration with the United Nations Environment Programme (UNEP).

Sudo, T. (2006). Japanese Voluntary Emissions Trading Scheme (JVETS) - Overview and Analysis. Presentation made at the US-Japan Workshop on Climate Actions and Co-benefit, March 22-23, 2006. Available at <http://www.iges.or.jp/en/cp/pdf/activity06/07.pdf>

Terrell, R. (2010). Japan Rejects Cap and Trade. Available at <http://www.thenewamerican.com/index.php/tech-mainmenu-30/environment/5707-japan-rejects-cap-and-trade>

UNFCCC website, GHG Data from UNFCCC. Available at: http://unfccc.int/ghg_data/items/3800.php .

UNFCCC website, GHG Data 2006, Highlights of GHG Emissions Data from 1990-2004 for Annex I Parties, Available at http://unfccc.int/files/essential_background/background_publications_htmlpdf/application/pdf/ghg_booklet_06.pdf .

UNFCCC website (2010). Copenhagen Accord. Available at <http://unfccc.int/resource/docs/2009/cop15/eng/11a01.pdf>

Vickrey, W. 1961. Counterspeculation, Auctions, and Competitive Sealed Tenders. *Journal of Finance* 16 (1) 8–37.

Weitzman, Martin L. (1974). Prices vs. Quantities. *The Review of Economic Studies*. Vol. 41(4). 1974. Pp. 477-491.

Wilder, M. and Fitz-Gerald, L. (2008). Overview of Policy and Regulatory Emissions Trading Frameworks in Australia. *Australian Resources and Energy Law Journal (ARELJ)*, (2008), 27(1).

William Chandler (2008). Breaking the Suicide Pact: U.S.- China Cooperation on Climate Change. Carnegie Endowment for International Peace. May 2008.

Wood, P.J. (2010). Climate Change and Game Theory. Research Report No 62. Environmental Economics Research Hub. Crawford School of Economics and Government, The Australian National University. ISSN 1853-9728.

Wong, P. (2008). Climate Change: A Responsibility Agenda. Speech by the Minister for Climate Change and Water to the Australian Industry Group Luncheon. Melbourne. February 2008.

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