INTERNATIONAL ENVIRONMENTAL AGREEMENTS: INCENTIVES AND POLITICAL ECONOMY

by

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Abstract

International environmental agreements are increasingly important in a globalised economy. Beyond their specific interest, these agreements are also important in the context of coalition formation theory. Given the incentives to free ride, associated to the environment as a public good and to the presence of spillovers, the profitability and the optimality of environmental agreements are separated from their stability (i.e. self-enforcement): hence, a whole set of political economy issues. This paper reviews the recent advances in this area. In particular it discusses mechanisms and strategies aimed at offsetting the incentives to free ride and increasing welfare, such as transfers, issue linkages, threats and multiple agreements. The main results show that partial coalitions and multiple agreements tend to prevail among subsets of players, and that agreements among all players are most unlikely to exist. The design of the agreements, moreover, can be crucial in determining the number of signatory countries.

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1. Introduction

International agreements among sovereign nations are increasingly important in a globalised economy. The range of topics is wide. Transnational issues, such as trade and financial flows liberalisation, migrations, technological cooperation, development-aid and environmental protection are the most important problems discussed in G-7 and EU meetings as well as in big international conferences aimed at approving world-wide conventions on specific matters. The common feature of the issues under discussion is a high degree of interdependence among countries: in general, the welfare of each country depends on its own action as well as on the action by any other country so that, in some cases, unilateral policies can be jeopardised and possibly made useless by spillovers. Hence, the need for policy coordination.

Among the transnational policy issues, environmental protection is a limiting case. In areas such as global warming, ozone layer depletion and bio-diversity, spillovers as well as the absence of clear property rights create strong incentives to free ride which undermine cooperation. Hence, the difficulty to reach agreements which are both effective and widely accepted. Given the difficulties involved, therefore, environmental agreements are a benchmark in the theory of coalition formation. The incentives to free ride, indeed, determine the separation between the profitability and optimality of the agreements and their stability. As a consequence, normative and positive analyses diverge and give rise to several political economy issues.

Early contributions (Cf. Hardin and Baden 1977) characterised the environmental-game among countries as a prisoners' dilemma, inevitably leading to the so-called "tragedy" of the common property goods. But in the real world, at the same time, a large number of international environmental agreements on the commons was signed, often involving sub groups of negotiating countries and sometimes involving transfers and other links with other policies (trade, technological cooperation etc.). Against this background, from the 1990s, the theoretical literature is trying to understand the logic of coalition formation in the presence of spillovers, and the possibility to increase welfare by means of appropriate mechanisms and strategies. To this purpose, the literature is following two main directions: (i) cooperative games; (ii) non-cooperative games.

In cooperative game theory, the focus of analysis is the coalition of countries and its characteristic function, i.e. the total net benefits the coalition can share. Work by Chander and Tulkens (1997) showed that, in the case of the global commons, the core of the game is non-empty. In addition, a recent paper by Uzawa (1997) demonstrates that, under specific assumptions, the core of the cooperative game corresponds to Lindahl equilibrium.

Non cooperative game theory, on the contrary, focuses on individual countries which maximise their own welfare, subject to the individual welfare maximising behaviour by other countries. Games can be repeated (Barrett, 1997b) as well as one-shot (Barrett, 1994; Carraro and Siniscalco, 1993; Hoel, 1992). In both cases, the analysis focuses on coalition formation mechanisms, i.e. on the incentives that lead to self-enforcing international agreements and define the number of the signatory countries.

In this paper we focus on non-cooperative games. We believe that cooperative games are interesting in providing a benchmark, but either assume the existence of a coalition or ignore the stability problems related to the incentives to free ride. Among non-cooperative games, we particularly concentrate on one shot coalition formation games, as they do not need the special assumptions (on collective rationality or on discount rates) which are needed to avoid folk theorems in repeated games.

2. Theoretical Framework

The theoretical framework which is used to analyse the feasibility of international environmental agreements is the non cooperative game theory of coalition formation. Following this approach, countries facing an international environmental problem play a two-stage game. In the first stage -- the coalition game -- they decide non cooperatively whether or not to sign the agreement. In the second stage, they play the non cooperative Nash emission game, where the countries which sign the agreement play as a single player and divide the resulting payoff according to a given burden-sharing rule (any of the rules derived from cooperative game theory).[1]

[1] This approach has to be contrasted with the traditional cooperative game approach (e.g. Chander-Tulkens, 1993, 1997) and with a repeated game approach (Barrett, 1994, 1997b). Moreover, notice that the regulatory approach often proposed in public economics is not appropriate given the lack of a supranational authority.

Moreover, let us assume that:

- All countries decide simultaneously in both stages;[2]

- Countries are proposed to sign a single agreement. Hence, those which do sign cannot propose a different agreement. From a game-theoretic viewpoint this implies that only one coalition can be formed, the remaining defecting players playing as singletons.[3]

- When defecting from a coalition *s*, each country assumes that the other countries belonging to *s* remain in the coalition.[4]

- Each country's payoff function increases monotonically with respect to the coalition size (the number of signatories in the symmetric case).[5]

Given these assumptions, we say that:

- A coalition *s* is profitable when each country $i \in s$ gains from joining the coalition (with respect to its position when no countries cooperate). Formally, a coalition *s* is profitable iff $P_i(s) \geq P_i(\varnothing)$, $\forall i \in s$, where $P_i(s)$ is country i's payoff when coalition *s* forms.

- A coalition *s* is stable iff:
(i) there is no incentive to free-ride, i.e. $Q_i(s \setminus i) - P_i(s) < 0$ for each country i belonging to *s,* where $Q_i(s \setminus i)$ is country i's payoff when it defects from coalition *s;*

[2] By contrast, Barrett (1994) assumes that the group of signatories is Stackelberg leader with respect to non-signatories in the second stage emission game. In Bloch (1997) it is assumed that countries play sequentially in the first stage coalition game.

[3] This assumption will be relaxed later on.

[4] This assumption is equivalent to the assumption of "Nash conjectures" in a simultaneous oligopoly game where a player assumes no change in the other players decision variable when it modifies its own decision variable. However, coalition theory often uses a different assumption, named coalition unanimity (Cf. Bloch, 1997), where the whole coalition is assumed to collapse when one of its members defects (see Chander and Tulkens, 1993, 1997).

[5] The implications of relaxing this assumption will be discussed in Section 4.

(ii) there is no incentive to broaden the coalition, i.e. $P_i(s^{\cdot\cdot} \; i) - Q_i(s) < 0$ for each country i which does not belong to s.[6]

- A profitable and stable coalition s is also Pareto optimal iff there exists no other profitable and stable coalition which provides all countries with a payoff larger than $P_i(s)$, $\forall i \in s$. Formally, $P_i(s) \geq P_i(s^*)$, $\forall i \in s$, $s \in S$, $\forall s^* \in S$ such that $i \in s^*$, where S is the set of all stable and profitable coalitions. Notice that a profitable and stable coalition is also Pareto optimal under the assumption that a country's payoff function increases monotonically with the coalition size.

3. Background

Work on profitability and stability of international environmental agreements has emphasised a few important results:[7]

(i) The game structure which captures countries' interactions is not a prisoners' dilemma but rather a chicken game in which at least two groups of players (and two roles: signatories and defectors) co-exist (Carraro and Siniscalco, 1993). More precisely, a profitable and stable, but partial, coalition emerges out of the two stage-game described in Section 2. Therefore, the equilibrium of the game is not the one in which no cooperation takes place (no countries sign the agreement) as could be expected given the characteristics of the global environment (a public good with spillovers). At the equilibrium there are instead two groups of countries, signatories and defectors, where the size of the group of signatories crucially depends on the slope of countries' reaction functions.

(ii) The previously mentioned stable (and Pareto optimal if the payoff function increases monotonically) coalition is generally formed by a low number of players.[8] Hence, the research

[6] This definition of stability coincides with the definition of a stable cartel provided in the oligopoly literature (D'Aspremont *et al*, 1983) and defines the Nash equilibrium of the first of the game (the one in which countries decide whether or not to sign the agreement). Notice that stability coincides with profitability under coalition unanimity.

[7] These results have been shown analytically for the case of symmetric countries (Carraro and Siniscalco, 1993; Barrett, 1994) but were also confirmed by numerical simulations in the case of asymmetric countries (Barrett, 1997a; Botteon and Carraro, 1997a).

[8] This conclusion depends on the assumption on the returns from abatement activities and on the presence of abatement fixed costs (Barrett, 1994; Heal, 1994).

focused on ways of broadening the endogenous stable coalition by introducing appropriate policy measures which go beyond emission control. Three ideas deserve our attention.

- Transfers

Transfers are often proposed to tackle the profitability dimension of international negotiations, i.e. to compensate those countries which, because of their asymmetries, would lose from signing the agreement. Transfers may also be an important tool to expand an originally stable, but small, environmental coalition. However, as shown in Carraro and Siniscalco (1993), countries which accept to implement a transfer program to non-signatories must be committed to cooperation (this condition is weaker with asymmetric countries; see Botteon and Carraro, 1997a). As a consequence the international agreement becomes partially self-enforcing.

- Issue linkage

As for transfers, the linkage of environmental negotiations to other economic issues (e.g. trade, technological cooperation) may be useful: (a) to reduce the constraints that asymmetries impose on the emergence of stable environmental agreements;[9] (b) to increase the size of the stable coalition. This second objective can be achieved even when all countries gain from signing the agreement if issue linkage is designed to offset countries' free-riding incentives (Cf. Carraro and Siniscalco, 1995). This is the case when the negotiation on an issue with excludable benefits (a club good) is linked to the environmental negotiation (which, if successful, typically provides a public good, i.e. a non-excludable benefit). An example could be the linkage of environmental negotiations with negotiations on technological cooperation whose benefits are largely shared among the signatories whenever innovation spillovers to non-signatories are low (Cf. Carraro and Siniscalco, 1997).[10]

- Threats

The number of signatories of an international environmental agreement could be increased were non signatories threatened to be punished through adequate economic (e.g. trade) sanctions (Cf. Barrett, 1997b). However, credible threats are difficult to design. Emissions themselves are hardly a credible threat, because countries are unlikely to sustain self-damaging policies (e.g. when the "social clauses"

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[9] This point was made by Folmer et al (1993) and Cesar and De Zeeuw (1994).

[10] An extension to the case of structurally asymmetric countries is provided in Botteon and Carraro (1997b), whereas information asymmetries are accounted for in Katsoulacos (1997).

of GATT are violated). Moreover, in this case, asymmetries play a double role. On the one hand, some countries may not gain from signing the environmental agreement; on the other hand, some countries, even when gaining from environmental cooperation, may lose from carrying out the economic sanctions. This may reduce the effectiveness of threats in increasing the number of signatories of international environmental agreements.

4. New Developments and Extensions

New developments follow three directions, each originating from removing the assumptions of the standard framework described in Section 2.

-Non-monotonic payoff function

The literature discussed in Section 3 assumes that a country's payoff function $P_i(s)$ is monotonically increasing with the coalition size, i.e. with the number of signatories when all countries are symmetric. Monotonous payoff functions may not always be appropriate, as suggested by Yi and Shin (1994). Carraro and Siniscalco (1997) provide an example showing humped-shaped payoff functions when negotiations on environmental cooperation are linked with negotiations on R&D cooperation. [11]

Let $L_i(s) = Q_i(s\backslash i) - P_i(s)$ be country i's stability function. When positive, it shows that country i has no incentive to defect from coalition s. In the symmetric case, the intersection between $L_i(s)$ and the horizontal axis, where the number of countries is shown, defines the stable coalition which is formed by j* signatories (see Figure 1). However, j°, the optimal number of countries in the joint coalition (the maximand of the payoff function), may be lower than the number of countries belonging to the stable group of signatories of the joint agreement. As a consequence, three groups of countries may emerge (three roles): (a) those which cooperate (j°); (b) those which would like to cooperate but are excluded from the agreement and are therefore forced to non-cooperation (j*-j°); (c) and those which prefer not to cooperate (free-riders: n-j*). This case is depicted in Figure 1.

[11] The reason is that R&D cooperation provides a competitive advantage to signatories which can exploit a more efficient technology and therefore produce at lower unit costs. However, the competitive advantage tends to disappear when the number of signatories increases because an increasing number of countries share the same more efficient technology. On the other hand, there are diminishing returns of R&D cooperation. This implies that it may be optimal to exclude some countries from the joint R&D and environmental cooperation (the so-called exclusive membership stability of Yi and Shin, 1994).

- Multiple agreements

The standard stability concept of Section2 is derived from cartel theory (D'Aspremont-Jacquemin, 1983). There are several restrictive features of this stability concept: (a) only deviations by singletons are allowed; (b) players are not farsighted; (c) a single agreement is proposed and defectors cannot join to sign a different one, i.e. multiple coalitions are not allowed. If the stability concept is modified, conclusions may obviously be different. In particular, when countries deciding not to sign a given agreement can propose a different one among themselves, several equilibria may emerge.

Following Bloch (1997), it can be shown that the equilibrium coalition structure depends on the equilibrium concept which is adopted. Let us consider the Coalition Proof Nash equilibrium concept and let us still assume that players choose simultaneously which agreement to sign, i.e. which coalition to belong to. The results that can be derived from applying these theoretical refinements to a simple model of climate change negotiations are quite interesting and share some common features:

- the equilibrium coalition structure is not formed by a single coalition. In general, many coalitions form at the equilibrium[12];

- the grand coalition, in which all countries sign the same environmental agreement, is never an equilibrium;

- coalitions of different sizes may emerge at the equilibrium (even when countries are symmetric).[13]

These results are not enough to identify the characteristics of the likely outcome of negotiations on a given environmental issue. In some cases coalition structures are very dispersed, in other cases, coalition structures are quite concentrated. However, in general we can claim that there will be more

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[12] For simultaneous games, this result is shown in Yi and Shin (1994). For sequential games the proof is in Bloch (1994). A survey of different approaches to multiple coalition games is provided by Bloch (1997).

[13] The specific results on the size of the coalitions depend on the model structure and in particular on the slope of countries' reaction functions. If these are orthogonal and countries are symmetric, then two main types of equilibrium coalition structures emerge. (a) A coalition structure formed by many small coalitions (three countries in each coalition) and one or two singletons if n, the total number of countries, is not a multiple of three. (b) A coalition structure defined by the Fibonacci decomposition of n. For example, if 15 countries negotiate, the coalition structure is defined by two coalitions, one of 9 and one of 6 countries.

than one coalition at the equilibrium. Therefore, the effort to achieve a single environmental agreement at the world level seem to be inconsistent with countries' incentives to sign the agreement. The goal should probably be the achievement of two or more agreements. Notice that this latter claim contains an extension of previous theoretical results, derived in the case of symmetric countries, to the case of asymmetric countries. Unfortunately, there is no theoretical analysis that can support this type of extension, which can therefore be accepted only as very preliminary.[14]

- Coalitional behaviour

In the previous sections, it was assumed that a defector believes that the coalition will not collapse when he leaves it (this type of Nash conjecture is quite obvious in a simultaneous game). At the other extreme, we already mentioned that some authors (Tulkens, 1997) assume that a defection is always followed by the defection of all other countries (this assumption is called coalition unanimity), which implies that stability and profitability conditions coincide. There are two other assumptions on coalitional behaviour that may be considered:

- Chew (1994), Brams (1995), Mariotti (1997) propose to consider only equilibrium strategies in which countries take into account the ultimate consequences of their decisions to join or to leave a coalition (farsighted strategies). Therefore, when a country defects from a coalition *s*, it does not compare its coalition payoff $P_i(s)$ with its defection payoff $Q_i(s/i)$, but it rather compares $P_i(s)$ with the payoff it would get after all consequences of its defection, and therefore all possible subsequent defections and aggregations, are accounted for (Cf. Echia and Mariotti, 1998);

- alternatively, it would be possible to apply a concept of coalition rational conjectures that implies that the ex-ante conjecture on the response of the other countries to a given defection coincides with the actual ex-post reaction of these countries.[15]

These two concepts, albeit similar, have different implications. For example, whereas the grand coalition can be an equilibrium coalition using the idea of farsighted stability, this is not the case

[14] However, results contained in Barrett (1997a), Botteon and Carraro (1997a) for the case in which a single coalition is assumed at the equilibrium, suggest that theoretical results derived for the case of symmetric countries are largely confirmed when countries' asymmetries are introduced into the model. More work on this issue would nonetheless be very important.

[15] The idea is similar to the one of consistent conjectural variations proposed by Bresnaham (1981) in the oligopoly literature.

using the idea of coalition rational conjectures. Further work into this direction in nonetheless necessary, for example in translating the implications of the above analyses into agreement design (e.g. by introducing coalition unanimity in the agreement as in the case of the Maastricht treaty).

5. Political Economy

The literature on coalition formation analysed so far will develop in the next few years and interesting results are expected. In particular, the interest in environmental agreements will continue, given their importance and their analytical characteristics. In this area, two main lines of development can be envisaged. The first line of development is theoretical, and will lead to new equilibrium concepts and new refinements. The second line of development will concentrate on the political economy issues which are related to the kind of results produced so far. Here below, we briefly mention some scope for further work, by asking some relevant questions which are already emerging among scholars.

(i) What is the relationship between international agreements and national voters, given that agreements and conventions often need to be ratified by voters or parliaments? (For a discussion Cf. Currarini and Tulkens, 1997).

(ii) The incentive to cooperate even in the presence of free-riding may lead to the emergence of new international institutions, with a coordination role, rather than a regulatory one (Compte and Jehiel, 1997 propose an international arbitrator). How is it possible to solve the conflict between optimality and stability of a coalition depicted in Figure 1?. Under what conditions do countries belong to one of the three groups? When do voters choose the first (second, third) role?

(iii) The above political economy issues emerge both when countries are symmetric and when they are asymmetric. In the asymmetric case a further issue arises: a given country i may prefer some countries, say j and h, as partners in the cooperating group, but these countries may want to sign the agreement with country k, rather than with i. Which negotiating and voting process leads to the efficient outcome? Is it possible that linking two (or more) issues leads to no equilibrium (because there is no agreement on the members of the cooperating group) or to an equilibrium in which a small number of countries cooperate (because there is an incentive to exclude some others)?

(iv) From the discussion in section 4, it is clear that the possibility of multiple agreements opens several political, institutional, and political economy issues. In particular, through which political process can we move from the negotiation on a single agreement to negotiations on multiple regional agreements ?

The above issues are already the object of investigation by economists. Some answers will come from theory. It will be a success when these answers will be translated into better agreements design. The political and diplomatic experience in several areas, from the environment, to trade, to currency areas and single currencies shows that the architecture of agreements can be the source of serious problems as well as of brilliant solutions.

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FIGURE 1. EQUILIBRIUM GROUPS OF COUNTRIES WITH LINKED NEGOTIATIONS