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**GLOBAL EXTERNALITIES
SOVEREIGN STATES**

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by

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Abstract

Trans-national externalities are increasingly important in the globalized economy, being related to knowledge, information, migrations, pollution, crime and similar flows. Their importance and close link to economic development may affect growth and welfare at a macroeconomic level: hence the need for global policies to correct their undesired effects. In the present institutional setting - with no supranational governing bodies - global externalities cannot be corrected by global institutions, which do not exist, but need to be corrected by voluntary agreements among sovereign States. This situation gives rise to several difficulties and sub-optimal outcomes. This paper reviews some recent advances in this area, with special reference to coalition formation theory. In particular it discusses mechanisms and strategies aimed at offsetting the incentives to free-ride and/or exclude countries for international agreements, such as transfers, issue linkages, and treatise design. The main results show that, in the presence of global externalities, partial coalitions and multiple agreements tend to prevail among subsets of countries, and that agreements among all players are unlikely to exist. The design of the agreements, however, can be crucial in determining the number of signatory countries and in promoting the creation of global institutions.

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1. Global externalities

Globalization is a new expression that does not appear in many dictionaries, even if it is increasingly used in the media and in the current debate. It obviously means "becoming global" or more precisely worldwide. But what is becoming global so recently and so intensely to need a new word?

In the last few years we observe increasing trans-national flows of goods, services, finance, direct investment, people, culture, knowledge, information, pollution, crime and the like. Such trans-national flows have been accelerated by technological, institutional and demographic changes. From an economic perspective they can be seen as the effect of a "worldwide arbitrage" and selection process.

The global flows under review are gaining momentum and are partly new, given the nature and characteristics of modern information, communication and transportation technologies. But globalization per se is a historical phenomenon that comes and goes in secular waves, and usually - but not necessarily - creates convergence (Cf Braudel, 1997; Foreman-Peck, 1998).

Trans-national and global flows imply greater interdependence among people, firms, governments, non-governmental and international organizations. In this context, for every agent (or country), welfare depends on her own action as well as on the other agents action. In general, the exchange of flows require markets and well defined property rights. Unfortunately, this is not always the case in the global economy. Some flows, such as pollution, knowledge, or migrations completely lack markets and prices: in this case we are in the presence of pure global externalities. Other flows, such as investment or raw materials go through markets and prices, but such markets are non-competitive: in this case we are in the presence of pecuniary global externalities. Typically, pure externalities affect welfare; in a sub-optimal world, pecuniary externalities affect welfare as well, and can be discussed in the same conceptual framework (For a discussion Cf. Laffont, 1987).

Summing-up, we live in a world of global externalities, which can be positive (viz. knowledge) or negative (viz. pollution). In general, such externalities prevent optimality, imply market failure and need to be corrected by policies in the appropriate jurisdiction. The optimal jurisdiction, in many cases, cannot be national. This happens whenever interdependence and trans-national spillovers jeopardize any unilateral effort to internalize the externality. In the latter case, given the absence of global or trans-national governing bodies, the only solution is left to voluntary agreements among sovereign States (in diplomatic language "treatises", "conventions", "protocols" and, in the weakest case, "policy coordination").

2. The environment as a benchmark-case of global externalities

Among the transnational policy issues, environmental protection is a very interesting case. On the substantial ground, the links between the environment, demographic and economic growth, give rise to one of the key challenges for the next millennium (Cf. Hobsbawm, 1994). On the institutional ground, spillovers and the absence of property rights, in areas such as global warming, ozone layer depletion and bio-diversity, create strong incentives to free ride which undermine cooperation. On theoretical grounds, finally, global environmental issues is giving rise to a lively and fruitful literature on coalition formation theory, which is a branch of non-cooperative game theory (Barrett, 1997; Carraro-Siniscalco, 1997). Given the difficulties involved, therefore, global environmental agreements has become a prototype of "difficult agreements" both in practice and in the theory of coalition formation. The incentives to free ride, indeed, determine the separation between the profitability and optimality of the agreements on the one hand, and their stability on the other hand. As a consequence, normative and positive analyses diverge and give rise to several political economy issues.

In the remaining sessions we concentrate on environmental deterioration and on the policies to prevent it. But the global governance issues involved in environmental protection can be seen as a benchmark case of policy coordination and treatise design in the presence of global externalities.

The economic literature on global environment evolved pretty rapidly. Early contributions (Cf. Hardin and Baden 1977) characterised the interaction among countries as a prisoners' dilemma, inevitably leading to the so-called "tragedy" of the global 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 began to study 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 early 1990s literature followed 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 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, 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. 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.

3. The 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

Moreover, let us assume that:

- All countries decide simultaneously in both stages;²

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.

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.

- 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 $P_i(s) \geq P_i(\Phi)$, $\forall i \in s$, 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. $Q_i(s|i) - P_i(s) < 0$ for each country i belonging to s , where $Q_i(s|i)$ is country i 's payoff when it defects from coalition s ;

(ii) there is no incentive to broaden the coalition, i.e. $P_i(s \cup i) - Q_i(s) < 0$ for each country i which does not belong to s .⁶

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.

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.

- 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.

4. Some results

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

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).

- 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 only partially self-enforcing.

- Issue linkage

As for transfers, the linkage of environmental negotiations to other economic issues (e.g. trade, technological cooperation, etc) 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" 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

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).

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.

The nature of the above conclusions intuitively applies to many global externalities, even if the incentives to free ride may be smaller than in the case of environmental spillovers.

4. New Developments and Extensions

New developments follow three directions, each originating from removing the assumptions of the standard framework described in Section 3.

-Non-monotonic payoff function: clubs

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. The same approach can be applied to any club (say a single currency) where profitability may decrease after a certain number of members is reached ¹¹

Let $L_i(s) = Q_i(s|i) - P_i(s)$ 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^o , the optimal number of countries in the joint coalition (the maximand of the payoff function), may be lower than the number of countries

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).

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.

- Multiple agreements: regional treaties

The standard stability concept of Section 2 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 equilibrium¹²;
- 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

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

These results are not enough to identify the characteristics of the likely outcome of negotiations on any given 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 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);

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.

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.

- 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 using the idea of coalition rational conjectures.

Treatise design

Further work into this direction is necessary, finally, in translating the implications of the above analyses into agreement design. A promising idea is to introduce coalition unanimity in the agreement (as in the case of the Maastricht treaty). In this case, it is possible to (formally) build in the treatise, the conjectures that can make it stable.

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 global externalities (and in the related agreements) will continue, given their growing 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. 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

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

(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. And when is it possible and optimal to by-pass the national level? (the general election of the European Parliament can be seen as a multiple agreement among individuals of different nations on a whole set of linked issues).

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 a better global governance, as indicated by the opening addresses by Mr Jospin and Mr Wolfensohn. The political and diplomatic experience in several areas, from the environment, to trade, to the global financial system single shows that the *architecture* of agreements can be decisive and be the source of serious problems as well as of brilliant solutions.

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