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The effects of R&D investments in international environmental agreements with asymmetric countries

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ABSTRACT

The paper examines the stability of international environmental agreements (IEAs) in a dynamic context where abatement levels are associated with the stock pollutant evolution. We underline two meaningful aspects of this matter. Firstly, we consider asymmetry among countries, dividing them in two types: developed countries that have a considerable environmental awareness and developing ones that pay a less attention to environmental preservation. Secondly, we introduce a positive externality in the cooperation where countries coordinate their R&D activities sharing the investments in order to avoid duplication of green activities. Otherwise, the non-cooperators support completely their R&D investments for clean technologies. These two aspects encourage the formation of stable coalitions till to determine conditions for which also the grand coalition is stable.

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1. Introduction

International environmental agreements (IEAs) among countries are due to solve pollution problems caused by not sustainable industrial activities. These agreements are very difficult to achieve because countries are contended between the aim to reduce pollution and their benefit as free riders. Although the high number of countries involved in the environmental policies to reduce greenhouse gas emissions, the reality shows that IEAs are ratified by few countries (see Kyoto Protocol in 1997, COP-15 in 2009 and COP-18 in 2012). Using a stability concept proposed by d'Aspremont et al. [12] in the study of cartels, the literature confirms the pessimistic result that the size of stable coalitions is small. This concept requires that for a signatory is not favorable to leave the agreement (internal stability) and for a non-signatory is not profitable to join the agreement (external stability). Standard theoretical models proposed by Carraro and Siniscalco [9], Hoel [16], de Zeeuw [28] highlight that a stable coalition is formed by few countries if they solve a Cournot game. Otherwise, the size of a stable coalition is between two cooperators and the grand coalition if players solve a Stackelberg game (see Barrett [1]; Diamantoudi and Sartzetakis [13]; Rubio and Ulph [25]). In the quoted literature countries are symmetric, but this is not a realistic conjecture since countries are different from one another in marginal benefits related to emissions and in vulnerability to environmental damage. Models that analyze IEAs among asymmetric countries have been proposed by Botteon and Carraro [7], Barrett [2], Finus and Eyckmans [14], Carraro et al. [10], McGinty [21], Chou and Sylla [11], Osmani and Tol [22], Biancardi and Villani [4], Fuentes-Albero and Rubio [15], and Pavlova and de Zeeuw [23]. In the previous papers, the dynamic side of environmental problem is not considered, but abatement processes require the study of the evolution of the stock pollutant. For this reason, authors such as Rubio and Casino [24], Rubio and Ulph [26], Biancardi [3] and de Zeeuw [28] have applied differential games and optimal control theory to study pollution control models. In Biancardi and Villani [5] we have

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considered both the asymmetry of countries and the dynamic pollution control. The results have showed that the asymmetry on the environmental awareness does not carry through stable coalitions composed by a large number of countries in a dynamic context.

The objective of our paper is to analyze the formation and the stability of international agreements in a model of pollution reduction at the lowest costs. The main contribution is to introduce R&D investments in green technologies in a model in which countries are asymmetric and the dynamic of pollution control is considered. Our model follows the approach proposed by Ruis and de Zeeuw [27] about the effects that a research joint venture yields on the size of stable coalitions. In particular, we assume that cooperators share their R&D investments in order to internalize the positive externalities of their efforts while outsiders support individually their R&D costs in green capital. Differently from the quoted literature, the R&D consideration in the model modifies the pay-off structures increasing the number of countries that would to realize a coalition. Moreover the model proposed allows for asymmetries on the environmental damage. We assume that countries are divided in developed countries that have a considerable environmental awareness and developing ones that pay a less attention to environmental preservation. Considering a non-cooperative game, we propose a two stage game in which in the first each country decides whether to stay or not in the agreement and, in the second, the abatement level is obtained. The results show that a large set of stable coalitions exist when R&D investments are considered. They can be composed by all developed or all developing, or by both types of countries. Moreover, the choice of asymmetry plays an major role about the stability of the grand coalition that can be realized by appropriate values of environmental awarenesses p_h and p_l and R&D costs.

The paper is organized as follows. In Section 2 we specify the model and we calculate the Feedback Nash equilibria for all players. In Section 3 we propose the stability concepts applying them to our model. In Section 4 a numerical analysis of the stability is proposed and in Section 5 the stability of the grand coalition is analyzed. The conclusions are detailed in Section 6.

2. The basic model

Let us assume to have n countries that decide to reduce their pollution emissions in order to improve the environmental quality. We have n_h developed countries and n_l developing ones; the first are industrially advanced with a great propension to environmental protection while the second are economically less developed and characterized by an industrial system without the controls to preserve the environment.

Initially the level of accumulated emissions is $s_0 \in \mathbb{R}_+$, while $s(t) \in \mathbb{R}_+$ is the current world level of the stock of emissions. Each country emits a level of pollution and we assume that the whole source of pollutant is denoted with L. In a realistic way, the global stock of emission depends on industrial activity performed by both developed and developing countries, and the level of industrial activity should be optimally chosen by countries taking into account the emissions associated to abatement level. In other world, L would be a function of the industrial activity of all countries, so that a trade-off between the benefits of higher levels of industrial activity and the costs due to lager pollution caused by such activity should appear in the dynamic constraint of accumulated emissions. The inclusion in the same model both the optimal choice of industrial activity and abatement levels as endogenous control variables leads to a much larger difficulty in the tractability. So we believe that it is worth pursuing even in the absence of pollution growth due to industrial activity in our model. Moreover, about the natural rate of pollution decay, as has been highlighted in the quoted literature, we denote it by k and we assume that is a positive constant, although there are pollutants that degraded in a short time, others that need of a long period, and pollutants not degradable when the concentration level becomes too large.

We denoted by $a_h(t),\ h = 1 \ldots n_h$ the abatement level for developed countries and $a_l(t),\ l = 1 \ldots n_l$ the abatement for developing ones. The differential equation that describes the dynamics of accumulated emissions is the following:

$$\dot{s}(t) = L - \sum_{h=1}^{n_h} a_h(t) - \sum_{l=1}^{n_l} a_l(t) - ks(t); \quad s(0) = s_0; \qquad (1)$$

2.1. Environmental cost

As is common in literature (see Calvio and Rubio [8]), the cost function is composed by three parts. We assume that abatement costs are given by the quadratic form $\frac{1}{2}a^2(t)$, otherwise the damage costs are represented by the linear form $\frac{1}{2}ps(t)$. The linearity assumption of the damage cost is a considerable simplification but we expect that the impact of this choice on the results to be quantitative and not qualitative. However our assumption is supported by other papers, such as Breton et al. [6], Hoel and Schneider [18], Masoudia and Zaccour [20] and Labriet and Loulou [19]. It would be of interest to extend the analysis to a non-linear damage cost in future papers. The positive parameter p denotes a measure of the environmental awareness; in particular it is the relative weight attached to the damage costs as compared to the abatement costs. As countries are not identical, we propose an asymmetry with respect to environmental awareness. In particular we denote by p_l the common weight attached to damage costs of all developing countries and by p_h that of all developed countries. Obviously $p_l < p_h$. The third part of the cost function is related to the R&D investment in green capital and it is denoted by c. The total amount of R&D investment to develop a new technology that reduces abatement costs, requires a prevailing fixed threshold with respect to variable component and it is independent of the quantity of emissions. For these reasons, as pointed out in Ruis and de Zeeuw [27] and Hoel and de Zeeuw [17], we choice to assume the R&D investment as constant. We have the following cost functions:

$$C_h(t) = \frac{1}{2}a_h^2(t) + \frac{1}{2}p_h s(t) + c, \quad h = 1 \ldots n_h; \qquad (2)$$

$$C_l(t) = \frac{1}{2}a_l^2(t) + \frac{1}{2}p_l s(t) + c, \quad l = 1 \ldots n_l; \qquad (3)$$

for each developed and developing country, respectively.

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