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Research paper

Sharing R&D investments in international environmental agreements with asymmetric countries

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ABSTRACT

This paper studies the coalition formation and the stability of the International Environmental Agreements (IEAs) in a pollution abatement dynamic model. We point out two meaningful aspects of this topic. Firstly, we consider asymmetry among countries, dividing them into two types: developed countries with a considerable environmental awareness and developing ones that pay less attention to environmental preservation. In addition, the former have a high-technology industry that allows for a unit abatement cost lower than the latter, and that are characterized by a labour-intensive industrial structure. Secondly, we introduce a positive externality in the cooperation by considering the R&D investment as two costs, namely the research investment and the developing cost. We assume that countries can coordinate their R&D activities by sharing their fixed research investments in order to avoid duplication of green activities. Moreover, by collaborating developing efforts, cooperators benefit from a reduction of a unit abatement cost higher than defectors. On the other hand, although non-cooperators completely support R&D investments for clean technologies, they realize lower abatements and benefits of a spillover effect due to development investments realized by cooperators. These two aspects could encourage the formation of stable coalitions.

1. Introduction

International Environmental Agreements (IEAs) among countries are the usual instrument used to coordinate their use of environmental resources and industrial activities. The negotiation and the formation of an IEA is very difficult to achieve because, firstly the participation of the states in agreement is voluntary and, secondly because countries contend between their aim to reduce pollution and their benefit as free riders. Despite the high number of countries involved in the environmental policies to reduce greenhouse gas emissions, the reality shows that IEAs are ratified by only a few countries (see Kyoto Protocol in 1997, COP-15 in 2009 and COP-18 in 2012). At the Paris climate conference (COP21) in December 2015, 195 countries adopted the first ever universal, legally binding global climate deal that sets out global actions to avoid dangerous climate change by limiting global warming. The agreement supports climate actions to reduce emissions and invites developed countries to promote efforts to encourage cooperation with developing countries improving their green production technologies with research and development investments.

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In the game theory literature two approaches have been used to model participation in IEA. The cooperative approach assumes that players always coordinate their actions and concentrate on the collective optimization of the problems; in this way the existence of a coalition of players is taken for granted. On the other hand, the noncooperative approach uses a stability concept proposed by [14] in the study of cartels. 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 static models proposed by [11,18,28] 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 [1,15,26]). In the previous cited 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 [4,25,27,28] have applied differential games and optimal control theory to study pollution control models. 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 Barrett [2], Biancardi and Villani [5], Botteon and Carraro [9], Carraro et al. [12], Chou and Sylla [13], Finus and Eyckmans [16], Fuentes-Albero and Rubio [17], McGinty [22], Osmani and Tol [23], Pavlova and de Zeeuw [24].

In [6,7] we considered both the asymmetry of countries and the dynamic pollution control. In the former, the results showed that the asymmetry of the environmental awareness does not persist throughout stable coalitions composed of a large number of countries in a dynamic context. However, the latter results indicate the existence of R&D investment in clean technologies encourage the formation of a stable coalition until the conditions for the stability of the grand coalition can be determined.

The aim of our paper is to analyze the formation and the stability of international agreements in an abatement dynamic model of pollution reduction at the lowest costs. We point out two meaningful aspects on this topic. Firstly, we consider asymmetry among countries, dividing them into two types: developed countries that have considerable environmental awareness and developing ones that pay less attention to environmental preservation. In addition, the former have a high-technology industry that allows for a unit abatement cost lower than the latter, and that are characterized by a labour-intensive industrial structure. Countries can choose whether to cooperate or defect. In particular, we assume that cooperators minimize the aggregate costs while defectors minimize their own efforts.

Secondly, we study the effects of the externalities in the R&D investments. In particular, we consider that they are composed of two costs, namely the research investment and the developing cost. We assume that cooperators can coordinate their R&D activities by sharing their research investment and to avoid duplications of green activities in order to internalize the positive externalities of their efforts. Additionally, we consider that defectors completely support their R&D costs in green capital and realize lower abatements. Moreover, by merging their developing investments, cooperators benefit from a greater unit abatement cost reduction than defectors. The goal of our paper is to show that these aspects could encourage the formation of stable coalitions.

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 apply the proposed stability concepts to our model. In Section 4 some numerical analysis of the stability are proposed while in Section 5 we define the time consistency for our model implementing some numerical applications. Finally, the conclusions are detailed in Section 6.

2. The basic model

We consider n countries that reduce their pollution emissions to protect the environment. They are divided into two types: n_h developed countries with advanced industry and special attention to environmental issues and n_l developing countries that are economically less developed with a labour-intensive industrial system that does not consider environmental preservation.

Let us assume that the initial level of accumulated emissions is $s_0 \in \mathbb{R}_+$, while $s(t) \in \mathbb{R}_+$ is the current level of the stock of emissions. The whole source of pollutants is the result of pollution produced by the number of developed countries n_h and developing ones n_l and take into account the parameters $\phi_h > 0$ and $\phi_l > 0$, which stand for the business-as-usual emission levels, depend on national technology, economic structure and the level of development. We denote $a_h(t), h = 1 \cdots n_h$ as the abatement level for developed countries and $a_l(t), l = 1 \cdots n_l$ as the abatement for developing ones. The dynamic of accumulated emissions is given by the following differential equation:

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

where $k > 0$ is the natural rate of pollution decay. Eq. (1) takes into account the link between the abatement of developed and developing countries and the related level of pollution produced by each country.

2.1. Environmental cost

Inspired by several papers quoted in literature (see for instance [10]), we propose a cost function composed of the abatement and the damage costs, the research and the development investments. In particular, we assume that abatement costs

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