Economics Letters 153 (2017) 1–5

Contents lists available at ScienceDirect

Economics Letters

journal homepage: www.elsevier.com/locate/ecolet

Adapting to climate change: Is cooperation good for the environment?☆

Nahid Masoudi [a], Georges Zaccour [b,*]

[a] Department of Economics, Memorial University of Newfoundland, Canada
[b] GERAD, HEC Montréal, 3000 Côte-Sainte-Catherine, Montréal, Canada, H3T 2A7

HIGHLIGHTS

- We consider an international environmental agreement on R&D in adaptation.
- When adaptation is a public good, the size of the IEA is large.
- The larger the cost of R&D in adaptation, the larger the coalition size.
- The smaller the technological spillover, the larger the coalition size.
- Adaptation and cooperation increase total pollution.

ARTICLE INFO

Article history:
Received 1 December 2016
Received in revised form 6 January 2017
Accepted 20 January 2017
Available online 21 January 2017

JEL classification:
C71
Q55

Keywords:
International environmental agreement
Climate change
Adaptation
R&D
Spillover

ABSTRACT

We consider the formation of an international environmental agreement focusing on adaptation to climate change. Members of the agreement fully share their knowledge and determine their investments in R&D by maximizing their joint welfare, while non-members optimize their individual payoffs. Using a three-stage game formalism, we obtain that a large coalition is achievable and that total emissions increase with the size of the agreement. The welfare implications are parameter dependent.

1. Introduction

A considerable effort has been deployed during the last two decades to design and implement international environmental agreements (IEAs) to control global warming and climate change. These agreements, e.g., the Paris Agreement, the Kyoto Protocol, pursue a strategy of voluntary emissions reduction. The literature and the experience with the Kyoto Protocol, offer a pessimistic view on voluntary reductions because the parties have incentives to free ride on the agreement, i.e., let others do the effort while enjoying a better environment (see the recent survey in Marrouch and Chaudhuri (2016)). Even if the Paris Agreement is duly implemented, we already have unleashed the climate change and the impacts of the long-lived greenhouse gases will persist for decades. Therefore, notwithstanding the necessity of reducing emissions, adapting to climate change is also a necessity, with adaptation defined as "finding and implementing sound ways of adjusting to the adverse effects of climate change" (UNFCCC, 2006).

The literature looking at IEAs with adaptation is recent and sparse (Benchekroun et al., 2017; Lazkano et al., 2016; Masoudi and Zaccour, 2016). In the first two references, adaptation is a private good. In this paper, we follow Masoudi and Zaccour (2016) and assume that adaptation has a public good flavor. The rationale is that knowledge in adaptation technologies may not be fully appropriable, and even if it were, cooperation may be attractive because a technology, e.g., an early warning and evacuation system, can be useful to many countries. Whereas in Masoudi and Zaccour (2016) the IEA members jointly optimize their welfare with respect to

☆ Research supported by SSHRC, Canada, grant 435-2013-0532. We would like to thank the Reviewer and the Editor for their helpful comments.
* Corresponding author. Fax: +1 514 340 6556.
E-mail addresses: nmasoudi@mun.ca (N. Masoudi), georges.zaccour@gerad.ca (G. Zaccour).

http://dx.doi.org/10.1016/j.econlet.2017.01.018
0165-1765/

both emissions and investments in adaptation, here we look only at a one-sided agreement, namely, coordination of R&D. This setting is similar to the R&D literature in industrial organization where firms can choose to be part or not of a research joint venture and share information, but in any event they compete in the product market (see the seminal paper by d'Aspremont and Jacquemin (1988)). Cooperation on emissions has been so far elusive and it is clearly of interest to analyze the consequences of an IEA that only concerns adaptation. Our aim is to address the following questions:

1. What is the stable size of an IEA on adaptation?
2. Does this IEA lead to higher emissions?
3. What are the welfare implications?

To answer these questions, we define a three-stage game. In the first stage, countries decide to join or not the agreement. Next, signatories choose their R&D levels that maximize their joint payoff, while each non-signatory maximizes its own private welfare. Finally, countries choose noncooperatively their emissions.

In a nutshell, our results indicate that a large IEA on adaptation is achievable and leads to higher emissions. So, the shared idea that if we are better at adapting, then we would care less about abating holds true in our context. The impact on welfare depends on the parameter values.

2. Model

As in Masoudi and Zaccour (2016), we consider a set $\mathcal{M}$ of symmetric countries indexed by $i = 1, \ldots, M$. Production of goods P_i in country i, generates revenues R_i and, as a by-product, pollutant emissions e_i, with $e_i = h_i(P_i)$, where $h_i(\cdot)$ is an increasing function satisfying $h_i(0) = 0$. Assuming a monotone increasing relationship between production and revenues, we can express revenues as a function of emissions, i.e., $R_i(e_i)$. Following the literature, see the survey in Jørgensen et al. (2010), we retain a quadratic (concave) functional form, i.e.,

$$R_i(e_i) = \alpha e_i - \frac{1}{2}e_i^2, \quad \alpha > 0.$$

Denote by $\mathcal{E}$ the total emissions, and by $D_i(\mathcal{E})$ the convex increasing damage cost given by

$$D_i(\mathcal{E}) = \frac{1}{2}\beta(\mathcal{E})^2, \quad \beta > 0,$$

where $\mathcal{E} = \sum_{i=1}^{M} e_i$. Country i can invest in R&D to develop a knowledge or means to adapt to a polluted world, i.e., reducing the negative impacts of pollution. Denote by κ_i the R&D effort and by $C(\kappa_i)$ its convex increasing cost specified as follows:

$$C(\kappa_i) = \frac{c}{2}\kappa_i^2, \quad c > 0. \tag{1}$$

Knowledge can be voluntarily shared between countries and is not fully appropriable. Denote by K_i the total knowledge available to i, i.e.,

$$K_i = \kappa_i + \text{knowledge spillover},$$

with the spillover being dependent on being or not member of the IEA. (More on measuring K_i in the next section.) This knowledge allows to reduce the damage to

$$D_i(\mathcal{E}, K_i) = \frac{1}{2}\beta\mathcal{E}^2 - \theta A\mathcal{E}, \tag{2}$$

where θ is a parameter defining adaptability and $A = F(K_i)$ represents the adaptation capacity resulting from the acquired knowledge, with $F(K_i)$ satisfying the following conditions: (i) $F(K_i) = 0$ for $K_i < \underline{K}$; (ii) $F(K_i) = 1$ for $K_i \geq \overline{K}$; and (iii) $0 < F(K_i) < 1$ for $K_i \in (\underline{K}, \overline{K})$, with $F'(K_i) > 0$ and $F''(K_i) \leq 0$, where $\underline{K}$ and $\overline{K}$ are positive parameters. Condition (i) states that if K_i is too low, then country i will not succeed in developing adaptation technologies. Conditions (ii) and (iii) say that knowledge is subject to marginal decreasing return and that there is a limit to adaptation. To illustrate, a country needs to acquire a minimum knowledge (in broad sense to include research infrastructure and personnel) to succeed in developing, e.g., a new crop adapted to the changing climate conditions. A higher knowledge capacity, can lead to higher yields, but up to a certain upper bound. We specify $F(K_i)$ as follows[1]:

$$F(K_i) = \begin{cases} 0 & K_i < \underline{K} \\ \dfrac{K_i - \underline{K}}{\overline{K} - \underline{K}} & \underline{K} \leq K_i \leq \overline{K} \\ 1 & K_i > \overline{K}, \end{cases} \tag{3}$$

i.e., if $\underline{K}$ is crossed, then $F(K_i)$ is the increment with respect to $\underline{K}$, divided by the range of useful knowledge defined by $\overline{K} - \underline{K}$. As the success of R&D activities is typically uncertain, the formulation in (3) could be interpreted as a uniform cumulative distribution for R&D effectiveness, with $\overline{K}$ being the level that provides an effective adaptation technology with certainty. To keep it simple, we normalize $\underline{K}$ to zero.

Country i's welfare is defined as

$$W_i = \alpha_i e_i - \frac{1}{2}e_i^2 - \frac{c}{2}\kappa_i^2 - \frac{1}{2}\beta\left(\sum e_i\right)^2 + \theta F(K_i)\sum e_i.$$

3. Results

We consider a three-stage game. In stage 1, the membership stage, each country decides to join or not the IEA. In stage 2, the R&D stage, countries choose their R&D efforts conditional to their choices in the first stage. In stage 3, the countries determine their emissions given the choice made in the previous two stages. To obtain a subgame-perfect Nash equilibrium, we solve the game backward.

3.1. Emissions stage

Denote by S the size of the treaty and by $N = M - S$ the number of non-signatories. The sets of signatories and non-signatories are denoted $\mathcal{S}$ and $\mathcal{N}$, respectively. Country i's problem is

$$\max_{e_i \geq 0} W_i = \alpha e_i - \frac{1}{2}e_i^2 - \frac{c}{2}\kappa_i^2 - \frac{1}{2}\beta\left(\sum_{i=1}^{M} e_i\right)^2 + \theta F(K_i)\sum_{i=1}^{M} e_i, \tag{4}$$

$$\text{subject to } \frac{1}{2}\beta\left(\sum_{i=1}^{M} e_i\right)^2 \geq \theta F(K_i)\sum_{i=1}^{M} e_i, \tag{5}$$

where the constraint stipulates that adaptation cannot turn pollution into a positive externality.

The following result gives emissions as a function of effective adaptation technology.

Proposition 1. *Suppose that S countries join the R&D treaty. Then, the equilibrium emission levels are*

$$e_i^S = \frac{\alpha + \theta F\left(K_i^S\right)}{1 + M\beta}, \quad i \in \mathcal{S} \tag{6}$$

[1] A simpler and very specific case of this function could be

$$F(K_i) = \begin{cases} 0 & K_i < \underline{K} \\ 1 & K_i > \overline{K}. \end{cases}$$