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Interfaces with Other Disciplines

The impact of foresight in a transboundary pollution game☆

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ABSTRACT

We study the impact of foresight in a transboundary pollution game; i.e. the ability of a country to control its emissions taking into account the relationship between current emissions and future levels of pollution and thus on future damages. We show that when all countries are myopic, i.e., choose the 'laisser-faire' policy, their payoffs are smaller than when all countries are farsighted, i.e., non-myopic. However, in the case where one myopic country becomes farsighted we show that the welfare impact of foresight on that country is ambiguous. Foresight may be welfare reducing for the country that acquires it. This is due to the reaction of the other farsighted countries to that country's acquisition of foresight. The country that acquires foresight reduces its emissions while the other farsighted countries extend their emissions. The overall impact on total emissions is ambiguous. Moreover, our results suggest that incentive mechanisms, that involve a very small (possibly zero) present value of transfers, can play an important role in inducing a country to adopt a farsighted behavior and diminishing the number of myopic countries. These incentives would compensate the myopic country for the short-run losses incurred from the acquisition of foresight and can be reimbursed by that country from the gains from foresight that it enjoys in the long run.

1. Introduction

It is well known that in a transboundary pollution game where emissions are a by-product of production and accumulate into a harmful stock pollutant, the non-cooperative equilibrium typically results in an over-polluted environment. Countries typically ignore the externality imposed on each other. An important feature of transboundary pollution games is that pollution emissions accumulate and therefore the action at any given moment has a lasting impact on the environment. The literature on dynamic pollution games (see Jørgensen, Martín-Herrán, & Zaccour, 2010 for a survey of dynamic pollution games and Bertinelli, Camacho, & Zou, 2014 and El Ouardighi, Sim, & Kim, 2016 for recent contributions to this literature) typically considers from the outset that all the players are farsighted, i.e., able to have an environmental policy to control their respective emissions. In this paper, we consider two types of behavior: (i) a country can be myopic and adopt a "laisser-faire" policy which amounts, in our framework to ignore the impact of its current emissions on the accumulation of pollution and (ii) a country can be farsighted and is able to control its emissions taking into account the impact of its emissions on the pollution stock.

A myopic country adopts a "laisser-faire" policy, which in a competitive market maximizes the benefit from consumption ignoring the damages caused by emissions. Using a "laisser-faire" policy can result from the inability (or unwillingness) of a government to legislate or to enforce an environmental regulation. Indeed, the authority to regulate polluting industries can require the passing of important pieces of legislation which can be a costly process. Thus, the analysis of the impact of foresight versus myopia is equivalent to the analysis of acquiring the means to regulate a polluting industry versus a "laisser-faire" policy. For example in the US, the Environmental Protection Agency gets the authority to write regulations from laws written by the US Congress, e.g. Clean Air Act or Clear Water Act. There is thus a first stage at the legislative level that authorizes the regulation agency to design and implement regulations. The "laisser-faire" scenario can be interpreted as a scenario describing a country that has not passed the legislation that authorizes regulation. We study in this paper the impact of the acquisition of foresight on the equilib-

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rium outcome of the transboundary pollution game à la Dockner and Long (1993) or Ploeg and de Zeeuw (1992) where the instantaneous welfare of each country is given by a benefit from consumption minus the damage caused by the stock of pollution. While in the case of a local pollutant, the decision to abandon "laisser-faire" amounts to a cost benefit analysis of regulating a local industry by a single decision maker, in the context of a transboundary pollution problem, this decision has strategic ramifications that need to be taken into account. We compute a Markov Perfect Nash Equilibrium of a differential game of transboundary pollution where a subset of players are myopic.

We would like to point out that the notion of foresight used in this paper and the related literature above is distinct from the notion of foresight used in the coalition theory literature. In that literature, a farsighted player is a player that is assumed to take into account the impact of his decision to leave or join a coalition on other players' decision to be in a coalition or not (see e.g., Diamantondi & Sartzetakis (2015) in the case of environmental agreements within a static framework or Breton, Sbragia, & Zaccour, 2010 and de Zeeuw, 2008 within a dynamic framework[1]). The objective is to study the size of stable coalitions and whether large coalitions can be self-enforcing. In our paper, we analyze the gains from foresight for a single player. Farsighted players in our framework are not assumed to jointly choose their emissions strategies as would a coalition of countries; they each maximize their own individual payoff while taking the strategies of the other countries as given.

In the case of a single decision maker the impact of foresight on the decision maker's welfare is clearly positive. Indeed, a farsighted country can still choose the path chosen under myopia and therefore the acquisition of foresight will typically allow the country to attain a higher level of utility.

In the case of several decision makers the impact of the acquisition of foresight turns out to be ambiguous, even in the limit case where the cost to acquire foresight is nil. It is in principle possible for a farsighted country to pick the same pollution path it would have chosen under myopia, however it is not necessarily true that the path chosen under myopia constitutes a best-response to the vector of strategies played by the other countries. The acquisition of foresight by a country typically induces that country to reduce its emissions compared to the case where it was myopic. The other countries respond to this reduction in emissions by increasing their emissions. In a multiplayer setup the reaction of other players (countries) is important and as it turns out can negate a goodwill gesture of a myopic country adopting a farsighted behavior (and reducing its emissions compared to the case where it was myopic). The sum of all countries' emissions may increase if one myopic player (country) became farsighted. This result is quite surprising, since myopia is generally associated with careless management of the environment and therefore one would assume that environmental quality unambiguously improves when a myopic country becomes farsighted. For a given total number of countries, the quality of the environment is not a monotonic function of the number of myopic countries. This is true for the short run only; we show that the acquisition of foresight by a country results in a decrease of the steady-state level of pollution. Thus, in the long run foresight results in a better quality of the environment.

We also examine the change in welfare from the acquisition of foresight and show that in a transboundary pollution game, contrary to a single decision maker problem, it can be negative. This can happen when the value of the damage parameter or when the stock of pollution is large enough. This is a rather pessimistic result since it is precisely in circumstances where pollution causes severe damage or when the stock of pollution is large that one would like all the countries to be farsighted and reduce their emissions. Numerical simulations reveal that, starting from an initial stock of pollution such that the present value of the gains from foresight is zero, the instantaneous welfare path of a myopic country crosses from below the path of instantaneous welfare it would enjoy if it were farsighted. Therefore, the change in instantaneous welfare from the acquisition of foresight is initially negative before turning positive. This suggests that incentive mechanisms, that involve a very small (possibly zero) present value of transfers, can play an important role in inducing a country to adopt a farsighted behavior and diminishing the number of myopic countries. These incentives would compensate the myopic country for the short-run losses incurred from the acquisition of foresight and can be reimbursed by the country from the gains from foresight that it enjoys in the long run.

This work was inspired by related studies on the impact of myopia or naive behavior in the area of management and marketing (see, for example, Benchekroun, Martín-Herrán, & Taboubi, 2009 and Martín-Herrán, Taboubi, & Zaccour, 2012, and references therein). Myopic behavior was also examined in the case of the fisheries. Sandal and Steinshamn (2004) examine the case of Cournot competition in the fisheries and allowed for the possibility that all or some players ignore the impact of their harvest on the resource dynamics. They considered the case where only one player is non-myopic and where the number of players is endogenous, and determined the condition under which a player becomes active. In contrast with Sandal and Steinshamn (2004) we find that if all players are myopic, then a player always benefits from unilaterally becoming non-myopic. This contrast can be explained by the fact that in their framework players are oligopolist in the market of output and therefore a change in the extraction of a player is met by a change (in the opposite direction) in the production of the myopic players as well as possible entry of new players. Whereas in the context of our transboundary pollution game, the business as usual level of emissions of myopic players is not affected by the emissions of the player that switch from myopic to non-myopic behavior. Moreover in the case of transboundary pollution the number of countries involved is fixed and not endogenously determined.

The next section presents the model and gives the Markov-Perfect equilibrium of the differential game where a subset of countries is myopic. The comparison of the case where all countries are myopic to the case where all are farsighted is given in Sections 3, and 4 gives the impact on the equilibrium outcomes of having one country changing from a myopic behavior to a farsighted behavior. Our results are summarized in Section 5.

2. Model

Consider $N+M$ countries indexed by $l = 1, \ldots, N+M$. Each country produces a single consumption good, the production of which generates emission of a pollutant. The preferences of consumers and the emission-consumption trade-off functions are such that the instantaneous benefits of country l from $E_l \geq 0$, the emission rates of country l, is $AE_l - \frac{1}{2}E_l^2$. The objective of country l is to maximize the discounted sum of utility net of the environmental damage caused by the accumulated stock of pollution, P,

$$\max_{E_l(t)} \int_0^\infty [AE_l(t) - \frac{1}{2}E_l^2(t) - \frac{s}{2}P^2(t)]e^{-rt}\,dt$$

where $s > 0$ is a damage parameter and $r > 0$ is the discount rate. The stock of pollution P accumulates according to

$$\dot{P}(t) = \sum_{l=1}^{N+M} E_l(t) - kP(t), \quad P(0) = P_0 \geq 0, \tag{1}$$

where $k > 0$ denotes the natural rate of decay.

We consider the case where M countries, indexed by $j = 1, \ldots, M$, are myopic. The emissions of a myopic player correspond to the emissions under a business as usual scenario or a "laisser-faire" scenario

[1] For more details see Calvo and Rubio (2012), a recent survey of the literature that uses dynamic state-space games to analyze the formation of international agreements to control pollution.