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International environmental agreements for local and global pollution ☆

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ABSTRACT

Increasing concerns about climate change have given rise to the formation of International Environmental Agreements (IEAs) as a possible solution to limit global pollution effects. In this paper, we study the stability of IEAs in a repeated game framework where we restrict to strategies which are simple and invariant to renegotiation. Our main contribution is that we characterize necessary and sufficient conditions for stability of an IEA when pollution has both a global and local effect. Local pollution spillovers are represented by a network structure. We find that stable IEAs exist if the network structure is balanced. Too large asymmetries in the degree of local spillovers may, however, lead to non-existence of stable structures. We also discuss the implications of our results for welfare. The generality of our approach allows for several applications, in particular the provision of public goods.

Introduction

Rising concerns about climate change has led politicians worldwide to rethink their countries' emission of greenhouse gases and air pollution. Doing what is best for their own countries' interest, however, does not fully internalize the global effects of the emissions and hence their optimal policy will not reduce pollution efficiently. In other words, countries free-ride on others' abatement efforts, similar to the case of private provision of public goods. To overcome this dilemma and achieve more efficient pollution abatement, several International Environmental Agreements (IEAs) have been proposed and formed in recent years.[1]

Besides their global effects, many forms of pollution have additional negative effects on countries within the same region of the polluting source. Air pollution, for instance, can cause smog, acid deposition and eutrophication which are mostly experienced locally while the global effects (e.g., global warming) are endured worldwide. Short-lived climate pollutants such as black carbon, methane and tropospheric ozone have both a local and global impact. Their effects on "regional and global climate, through both direct interaction with atmospheric radiation and indirect effects related to changes in cloud properties are a growing concern" (Committee on the Significance of International Transport of Air Pollutants; National

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[1] Examples include the Oslo Protocol on sulfur reduction in Europe (also including other states) in 1994, the Montreal Protocol on the depletion of the ozone layer in 1987 and the Kyoto-Protocol on the reduction of greenhouse gases in 1997.

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Research Council, 2009). As another example, a nuclear power plant causes higher negative effects in nearby regions by danger of malfunctioning compared to the global risk. The presence of these local spillovers hence plays a non-negligible role and adds heterogeneity to the problem of forming IEAs.

In this paper, we ask which IEAs may be implemented by purely self-interested countries when the negative externalities of pollution have a local and a global component. We use a repeated game approach of abatement efforts to study the stability of IEAs. An IEA, here, is a strategy profile in the repeated game which coordinates the abatement efforts of its members to maximize joint utility. We focus on simple strategies which give rise to punishment paths where the punishment lasts only one period and which can only be executed via higher emissions. By stability we mean that an IEA shall be self-enforcing in the sense that no member shall have an incentive to deviate from cooperation and renegotiation shall be prevented. Formally, we define an IEA as stable, if it is a weak renegotiation-proof equilibrium.

Which countries are affected by the local externality of pollution is represented by a network: a link between two countries indicates whether these countries' pollution affects each other locally. Here, a link could mean that two countries share the same border or are within some distance which is critical for the local externality. Given a local spillover structure, we derive optimal punishment strategies such that the grand coalition of all countries can be implemented as a subgame perfect equilibrium. In contrast to the general literature without a local spillover structure, global cooperation may fail to be a weakly renegotiation-proof equilibrium in very asymmetric networks, where the asymmetry is with respect to neighbors in the network. In other words, if the channels through which countries affect each other are very unevenly distributed, then global cooperation may fail. However, we also show that it can always be sustained in regular networks, i.e. networks such that all countries have the same number of neighbors.

The additional local spillover structure adds heterogeneity to the problem of stability of IEAs (in the sense of existence of a WRP equilibrium) and has interesting effects such that in some asymmetric structures, the global IEA is not a WRP equilibrium. As global pollution can be seen as a perfect public bad, the local side of it has the characteristics of a local public bad. Since reducing pollution has the characteristic of a public good, we also contribute to the problem of public good provision when the public good has both a local and a global component. To our knowledge, including both aspects in one model is also new to the literature of public goods.

Our results have important policy implications. When contemplating an IEA, strict rules have to be imposed in order to prevent deviation. These rules must specify the consequences of deviating from the agreed reductions and shall make use of the local spillover effects. With respect to welfare, we show in section "Social benefits and costs" that it is indeed better to first appoint neighbors for punishment of a deviation before non-neighbors shall punish. That is, neighbors of a deviator are more effective with their punishment since a deviator is punished through both the local and the global spillover channel and therefore the punishment path can be sustained more easily and requires fewer total emission.

More generally, the results may serve as a benchmark that can be useful in future analyses of IEAs. We point to several possible extensions in our "Conclusion" section. Moreover, the results can easily be transferred to other problems of public good provision and may support a better understanding of free-riding problems.

The paper is organized as follows: first, we further elaborate on the issue of local and global pollution and discuss related literature as well as our contributions. In section "A pollution game of local and global spillovers" we introduce the basic model of a single-stage game. In section "Stable IEAs in infinitely repeated games" we extend the model to an infinitely repeated game and derive conditions on existence of weakly renegotiation-proof equilibria for several prominent networks. The section "The stability of a global IEA" focuses on the welfare-maximizing global IEA. In section "Social benefits and costs" we analyze welfare implications of different network structures . Finally, section "Conclusion" concludes. All proofs are presented in the Appendix.

Background and literature review

International Environmental Agreements (IEAs) have been analyzed in various game-theoretic models over the past two decades. Starting with the seminal paper by Barrett (1994), several authors have studied the free-rider problem when joining an agreement by studying both one-shot and repeated games. For a good overview of the game-theoretic literature on environmental economics we refer to recent literature surveys such as for example Jørgensen et al. (2010) or Benchekroun and Long (2012). Formal models of climate cooperation are thoroughly reviewed in Hovi et al. (2015).

A majority of the models in the literature tackle the problem of air pollution, caused by the emission of greenhouse gases from fossil fuel combustion. While some models have at least abstracted from the stark assumption of homogeneous countries and introduced asymmetries to account for different impact and contribution levels of pollution (e.g., McGinty, 2007; Hannesson, 2010), the implications of geographical distance to the sources of air pollution have not been largely accounted for.

However, there is broad scientific evidence for the importance of regional characteristics for several air pollution effects. Most importantly, short-lived air pollutants, that include methane, black carbon and tropospheric ozone, have a significant local or regional impact besides contributing to global problems such as climate change (see, e.g., Kühn et al., 2013, for a study of emissions on local and global aerosol properties for China and India). Other examples for the regional effects of air pollution include the ozone level. For instance, the ozone level of the Mediterranean region is not only affected by local emissions but also perturbed by long-range pollution import from Northern Europe, North America and Asia (Richards et al., 2013).