



Climate agreements in a mitigation-adaptation game[☆]

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ABSTRACT

We analyze the strategic interaction between mitigation (public good) and adaptation (private good) strategies in a climate agreement. We show the fear that adaptation will reduce the incentives to mitigate carbon emissions may be unwarranted. Adaptation can lead to larger self-enforcing agreements, associated with higher global mitigation levels and welfare if it causes mitigation levels between different countries to be no longer strategic substitutes but complements. We argue that our results extend to many public goods. The well-known problem of “easy riding” may turn into “easy matching” if the marginal utility of public good consumption is strongly influenced by private consumption.

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1. Introduction

Climate change is probably one of the most important challenges of mankind. The Kyoto Protocol signed in 1997 was the first global treaty with specific mitigation targets but turned out to be not sufficient to

address global warming. After several years of negotiations, a successor agreement was recently signed in Paris in 2016. However, most scholars doubt that the Paris Accord will be sufficient to keep the increase of the global surface temperature below 2 °C, a widespread accepted target to avoid severe interference with the climate system.

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Clearly, mitigation to address the cause of global warming is costly, participation in a climate treaty is voluntary and compliance is difficult to enforce. Due to the slow progress of curbing global warming, and the first visible impacts of climate change, in particular in developing countries, adaptation measures (like building dykes against flooding and installing air-conditioning devices against heat) have received more attention in recent years. This is reflected in the negotiations leading to the Paris Accord but also in the scientific community, as for instance summarized by various recent reports by the Internal Panel on Climate Change (IPCC). In contrast to mitigation (i.e. reduction of emissions), which can be viewed as a non-excludable public good, adaptation (i.e. amelioration of climate damages) is usually viewed as a private good; it only benefits the country in which adaptation measures are implemented. The key research question which we try to answer is: how does adaptation, as an additional strategy to mitigation, affect the prospects of international policy coordination to tackle climate change?

At the outset, the answer is not straightforward when considering the following points. The “pessimists” argue that adaptation will shift the focus away from mitigation. Since typically the benefits from mitigation are lower in the presence of adaptation, equilibrium mitigation levels will be lower. Thus, also the positive welfare externalities across countries from cooperation are lower. The “optimists” point out that lower mitigation levels reduce the incentive to free-ride and hence larger agreements may be stable. Moreover, having a second strategy reduces the costs of addressing a global externality.

We show that the arguments of optimists and pessimists are correct, on balance, optimistic factors dominate the outcome, but the main driver for optimism is a very different one. In the presence of adaptation, reaction functions in mitigation space may be upward sloping. That is, mitigation levels in different countries may no longer be strategic substitutes but complements. Such a matching behavior makes it easier to form large stable coalitions in order to increase public good provision, which in most cases leads to larger global welfare.

The possibility of upward-sloping reaction functions arises when the substitutional or complementary relationship between equilibrium mitigation and adaptation in a country is sufficiently strong (to which we refer later as cross or indirect effect) compared to the substitutional relationship between own and foreign mitigation levels (to which we refer later as own or direct effect). It is interesting that this possibility does neither need the assumption that mitigation and adaptation are substitutes as is commonly believed (they can also be complements) nor does a large indirect effect need to imply that the sufficient conditions for the existence and uniqueness of equilibria are violated.

Our paper is related to four strands of literature. Firstly, there is large body of literature on the game-theoretic analysis of international environmental agreements (IEAs), which can be traced back to Barrett (1994) and Carraro and Siniscalco (1993), with recent publications for instance by Harstad (2012), El-Sayed and Rubio (2014) and Battaglini and Harstad (2016).¹ Only some recent papers have studied mitigation and adaptation in a strategic context. Different from for instance Buob and Stephan (2011), Ebert and Welsch (2011, 2012), Zehaie (2009) and Eisenack and Kähler (2016), we allow for more than two players and study the formation of agreements. Different from some recent work by Barrett (2008) and Benchekroun et al. (2017) who study IEAs, we work in a much more general framework, allow for the possibility that mitigation and adaptation could not only be substitutes but also complements and derive most results analytically. Also different from them, we allow for the

possibility of strategic complementarities in mitigation space, which is an important factor for generating interesting results.

Secondly, there is a literature on non-convexities of negative externalities, including early contributions by Baumol and Bradford (1972), Laffont (1976) and Starrett (1972). This literature does not consider agreement formation but points to the fact that private actions can ameliorate the damage from negative externalities. Noticing that any public bad game can be recasted in a public good game framework, where the latter is the setting of this paper, this means non-concavity of positive externalities. We show that in the presence of the amelioration of climate damages through adaptation, the conditions for upward-sloping reaction functions in public good provision space are exactly those related to the non-concavity of an agent's payoff function with respect to other players' provision levels, in line with this strand of literature.

Thirdly, there is a large literature on the private provision of (pure) public goods (e.g. Bergstrom et al., 1986; Cornes and Hartley, 2007; Fraser, 1992). “Private” means non-cooperative with the possibility of cooperative agreements normally not being considered in this literature. Typically, agents maximize a utility function subject to a linear budget constraint, with utility being derived from the total level of public provision (which is the sum of individual contributions) and a private numeraire good. The standard assumption is that both goods are normal goods, and the cross derivative of utility with respect to the public and private good is assumed to be of minor importance. This gives rise to downward sloping reaction functions in public good provision space and a unique equilibrium public good provision vector. However, downward sloping reaction functions, usually associated with the term “easy riding” (Cornes and Sandler, 1984), is not the only possibility as pointed out by Cornes and Sandler (1986, ch. 5). Moreover, it does not seem unrealistic to consider the possibility that some public goods are superior goods, like some environmental goods for which the income elasticities has been reported to be larger than 1. Our model essentially captures this possibility. Our utility function is called a benefit function but is essentially the same. What is different is that we do not assume a linear budget constraint with constant prices, but, in the tradition of the IEA-literature, consider the more general case of (strictly) convex cost functions of private and public good provision and hence non-constant marginal costs.² We have downward or upward sloping reaction functions, depending on the relative strength of own and cross effects on benefits, though importantly, only the absolute value (and not the sign) of the cross effect matters for the slope.

Fourthly, there is quite some literature that investigates complementarities in strategic games. From the survey by Vives (2005), it appears that complementarity does not need to be the result of special assumptions but there are many interesting economic problems with this feature, though the analysis is usually more complex, requires different tools for the analysis and may suffer from multiple equilibria. For our problem, it turns out that a slight modification of standard theorems is sufficient for the analysis and a simple condition gives existence and uniqueness of equilibria in both stages of the game.

It is important to note that the possibility of large cross effects on the benefits of public good and private good provision extends much beyond the context of this paper. For instance, member states of the European Community can either coordinate on policy issues like security, anti-terrorism, migration and social policy or pursue those issues nationally. That is, financial resources can either be transferred to Brussels (which can be interpreted as public good provision) or remain with national governments (which can be viewed as private good provision). In practice, national and international

¹ See Finus and Caparrós (2015) for a collection of some of the most influential papers in the field, including a comprehensive overview.

² This generalization comes at the cost that the problem can no longer be viewed in terms of income elasticities.

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