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International environmental agreements with ancillary benefits: Repeated games analysis☆

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ABSTRACT

Both ancillary and primary benefits, generated by climate change mitigation, are indispensable key factors to implement the full participation in international environmental agreement (IEA). This paper presents a new IEA model with ancillary benefits, using a repeated game with the linear and quadratic emission abatement cost functions of each country. This study also investigates the effect of ancillary benefits on the condition for full participation in IEA. Ancillary benefits function as a complementary device of punishment scheme for IEA. Our main results show that ancillary benefits can facilitate full participation in IEA, thus suggesting that they should be considered in climate change negotiations.

1. Introduction

International environmental agreements (IEAs) provide public goods such as the mitigation of climate change. The effectiveness of an IEA depends on the number of participating countries and the levels of public goods provisions. A new basic framework aimed at the prevention of global warming was compiled during the twenty-first session of the United Nations Conference of Parties (COP21), held in Paris, France, in 2015. Its scope was to uphold and promote regional and international cooperation to mobilize stronger and more ambitious climate action by all parties and non-party stakeholders.[1] However, each country's greenhouse gases (GHGs) emissions cause environmental damage all over the world, and a single country's public goods provision will benefit all countries in a non-exclusive and non-rival manner. Hence, all countries have an incentive to free ride on other countries' abatement efforts.

Previous research suggests that there are two types of international environmental public goods provision: the provision of *pure* public goods; and the provision of *impure* public goods (e.g., Aunan et al., 2007; Ekins, 1996a, 1996b; Finus and Rübbelke, 2013; Rive, 2010). The pure type has only public characteristics: climate change mitigation generates global scale public benefits that all countries equally receive by mitigation of climate change (primary benefits). The impure type has public and private characteristics: climate protection generates not only primary benefits, but also private benefits that only abating countries receive by individual climate protection (ancillary benefits). Whereas the primary benefits can be enjoyed globally, the ancillary benefits can only be enjoyed on a local scale. For example, climate protection behaviors reduce not only GHGs emissions but also sulfur dioxide (SO_2), nitrogen oxides (NO_x), and particulate matter (PM) emissions simultaneously.[2] Therefore, if a provision of public goods has private and public characteristics, it may affect the willingness of countries to participate in IEAs.

A considerable number of literatures have addressed the provision of global international pollution controls. Models of cooperation for

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[1] For more details, see UNFCCC (2016).

[2] For example, the ancillary benefits from reduction of secondary pollutants such as SO_2, NO_x, and PM, resulting from GHGs abatement has been highlighted as a potential catalyst for countries to engage in climate policy (Aunan et al., 2007; Ekins, 1996a, b). Rive (2010) assesses the co-benefit of the point source SO_2, NO_x, and PM emissions associated with regional climate policy in Western Europe. Finus and Rübbelke (2013) describe that many public goods are in fact impure public goods.

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climate control can be roughly divided into two groups: a participation game model where compliance is assumed; and repeated game model where compliance is ensured by the threat of future decreased abatement by punishing countries. The participation game model depicts the formation of agreements as a two-stage game. In the first stage, countries decide whether or not to sign an IEA. In the second stage, the signatories jointly choose the abatement levels, while each non-signatory independently chooses it abatement levels (e.g., Barrett, 1994, 2001; Carraro and Siniscalco, 1993; Finus and Rübbelke, 2013; van der Pol et al., 2012).[3] In the participation game model, no signatory deviates because we assume that all signatories abate in accordance with the agreement. Early studies of the participation game by Barrett (1994) and Carraro and Siniscalco (1993) demonstrate that the stable agreement is generally small. In summary, these studies demonstrate how difficult it is to forge an agreement with effective abatement levels and full participation under the participation game framework.

In a repeated game model, the game is infinitely repeated and we assume that the participation countries in the IEA are forced to cooperate at subsequent stages through credible threats (e.g., Asheim et al., 2006; Asheim and Holtsmark, 2009; Barrett, 1999, 2002, 2003; Froyn and Hovi, 2008).[4] The punishment is credible if the threats prevent the punishing countries from renegotiating and returning to cooperative behavior after a unilateral deviation. That is, the compliance is ensured by the threat of credible punishment in a repeated game model.

In this game model, agreements must specify a strategy that can enforce the signatories' cooperation. It must be the best interest for each country to individually act in accordance with the strategy (i.e., the subgame perfection requirement). Additionally, renegotiation must be prevented in such an equilibrium agreement (i.e., the renegotiation-proofness requirement). In particular, it must be in the best interest of the punishing countries to collectively punish a non-complying country before restarting the cooperative relationship. If these requirements are satisfied, the IEA can be sustained as a weakly renegotiation-proof equilibrium (in the sense of Farrell and Maskin, 1989).

Barrett (2002) demonstrates that a full participation agreement can be sustained, by limiting the per-country level (a consensus treaty). Asheim et al. (2006) present the *Regional Penance* strategy, which limits the number of punishing countries by only letting a deviation be punished by the other signatories in the same region, whereas signatories in the other region continue to cooperate. The results of Asheim et al. (2006) show that participation can be doubled in a two-region world. Froyn and Hovi (2008) propose a *Penance-m* strategy that specifies that only a subset of the signatories in a global agreement punish a deviator. The results of Froyn and Hovi (2008) show that a full participation agreement can be implemented as a weakly renegotiation-proof equilibrium within the linear abatement benefit and cost functions. Moreover, Asheim and Holtsmark (2009) show that full participation is possible using *Penance-m* within linear benefit and quadratic cost functions.

In the climate change context, it has been argued that preventing global warming generates not only primary benefits which all countries receive equally, but also ancillary benefits that the individual climate protecting countries receive privately. The ancillary benefits have attracted much attention in the context of emission abatement for climate change. In reality, the combustion of fossil fuels emits a range of secondary pollutants such as SO_2, NO_x, and PM. When each country reduces their use of fossil fuels with the objective of abating GHGs, these secondary pollutants are reduced simultaneously (Ekins, 1996a, 1996b; Aunan et al., 2007). Ekins (1996a, 1996b) shows that the consideration of ancillary benefits has a facilitating role for countries engaging in climate policy. Furthermore, Aunan et al. (2007) show the significance of ancillary benefits to China, that is, climate protection will reduce GHGs and local pollutants such as particles and NO_x. Therefore, abatement tends to resolve regional environmental problems such as those associated with domestic air pollution as well as global warming. Rive (2010) shows that considering the ancillary benefits of reducing SO_2, NO_x, and PM when designing policies increases the attainability of the abatement goals and the political feasibility of climate policies. Finus and Rübbelke (2013) investigate the effect of ancillary benefits on IEA participation. They take the pessimistic view that an agreement can be sustained if entered into by a few countries, and that the ancillary benefits have a neutral or negative impact on the number of signatories in a participation game framework.[5]

Although there has been significant analysis regarding the impact of ancillary benefits on international environmental policies and cooperation for mitigating climate change, there has been limited analysis of the strategic implications with respect to the cooperation of all countries. This paper investigates the effects of ancillary benefits of emission abatements on stable IEAs with full participation in a repeated game model, using the *Penance-m* strategy of Froyn and Hovi (2008). We consider two types of payoff functions: linear benefit and cost functions; and linear benefit and quadratic cost functions. An important focus of this study is the effect of ancillary benefits on the conditions leading to the formation of full participation IEAs.

Our main contributions are as follows. Using the two types of payoff functions, we show that full participation is still feasible even if we consider ancillary benefits. That is, this study generalizes the full participation weakly renegotiation-proof equilibria of Froyn and Hovi (2008) and Asheim and Holtsmark (2009) to the case of ancillary benefits, where abatement costs functions are linear and quadratic, respectively. Additionally, the results of this study are different from the results of Finus and Rübbelke (2013) and Froyn and Hovi (2008) because we consider a different situation. The negative effect of ancillary benefits on a stable IEA shown by Finus and Rübbelke (2013) disappears, if we consider a different situation where compliance is ensured by credible punishment threats. Compared to Froyn and Hovi (2008), the number of punishing countries decreases because of the ancillary benefits with linear costs, whereas this number remains unchanged with convex costs, if we consider a different situation where ancillary benefits are introduced.

The remainder of the paper is structured as follows. Section 2 presents a brief review of the *Penance-m* strategy. Section 3 describes our models and the weakly renegotiation-proof equilibrium outcomes. Section 4 compares the effect of ancillary benefits on the condition of weakly renegotiation-proof equilibrium for the two cases. Finally, Section 5 provides our concluding remarks and presents future scope for research.

2. The *Penance-m* concept

We assume that the cooperative relationship in the agreement is sustained by the *Penance-m* strategy of Froyn and Hovi (2008), which limits the number of countries that can punish a deviator, and show the feasibility of a weakly renegotiation-proof agreement with full participation and efficient abatement levels. Consider a world with $n \geq 2$ countries, where $N = \{1, \cdots, n\}$ denotes the set of all countries, and the grand coalition where all n countries participate. Each country decides

[3] To prevent climate change, the two (or more)-stage game is used not only in international policies such as IEAs but also in domestic environmental policies. For example, see Ouchida and Goto (2014, 2016).

[4] Hovi et al. (2015) categorize Asheim et al. (2006), Asheim and Holtsmark (2009), Barrett (1999, 2002, 2003), and Froyn and Hovi (2008) as the studies that demonstrate the IEAs formation within the repeated game framework.

[5] Finus and Rübbelke (2013) explain that countries that consider the private ancillary benefits to a greater extent will abate more emissions, irrespective of the IEAs. Hence, the relative importance of an IEA for climate protection is reduced.