OVERLAPPING INTERNATIONAL GREEN R&D AGREEMENTS

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Overview

Carbon Capture and Storage (CCS) has tremendous potential to reduce global carbon emissions. However, there are also substantial barriers that need to be overcome in order for this technology to be widely deployed; namely, the technology requires the financing of very large upfront costs (building the facilities and transportation networks), regulatory incentives (e.g., carbon pricing), coordination between public and private sectors in research development and demonstration (RD&D), and coordination between public and private sectors in the various issues associated with storage activities. Given the large dimensions of the tasks that must be accomplished, it is not surprising that Australia, Canada, China, the EU, India, Japan, Korea, Norway, South Africa, the UK and the USA, regions that are heavily dependent on energy produced from fossil fuels, are forming international partnerships to share efforts to enable them to eliminate obstacles and further develop and deploy CCS. Notably, China and EU are "hubs" in the international CCS network, since they have entered into multiple bilateral and multilateral international agreements. For example, China has bilateral agreements with Australia, the EU, Japan and the USA and a multilateral agreement with the EU and Norway.

In this paper, we consider benefits and costs associated with production of green R&D by international research collaborators in order to examine the efficiency and stability of hub-and-spoke, multilateral and isolated bilateral agreements. We focus on R&D that is produced by interactions among researchers.

Our paper contributes to the vast literature on international environmental agreements. The approach we utilize here deviates from the ones utilized in the literature on international environmental agreements because we consider individual and collective non-cooperative incentives to deviate with perfect foresight about current and future decisions of remaining coalition members in a setting where players are able to have unlimited pre-communication and to establish non-binding agreements. Coalition-proofness is a refinement of Nash equilibrium. As for our key contributions to the literature on environmental R&D, to the best of our knowledge, we are the first ones to model the production of collaborative R&D in overlapping international research networks and therefore consider the efficiency and stability of multilateral and hub-and-spoke international green R&D agreements.

Methods

We follow Silva and Zhu (2013), who extend the concept of perfectly coalition-proof Nash equilibrium advanced by Bernheim et al. (1987) to settings in which overlapping coalitions may coexist in the Nash equilibrium for multistage games. The extension is presented in Appendix A. It consists of employing the perfectly coalition-proof concept to the sets of players produced by the union of intersecting (i.e., overlapping) sets of players. Suppose, for example, that $N = \{1,2,3\}$ denotes the set of all players. In addition to N, the subsets of the set of all players are the singletons, $\{1\},\{2\},\{3\}$ and the pairs $\{1,2\},\{1,3\},\{2,3\}$. Let $(\{1\},\{2\},\{3\})$, $(\{1,2\},\{3\})$, $(\{1,3\},\{2\})$, $(\{1\},\{2,3\})$, $(\{1,2\},\{1,3\})$, $(\{1,2\},\{2,3\})$, $(\{1,3\},\{2,3\})$ and $(\{1,2,3\})$ be the relevant coalitional structures that may be produced by the coalition-proof refinement. The standard coalition-proof concept is applicable to all coalitional structures except to the overlapping ones, $(\{1,2\},\{1,3\})$, $(\{1,2\},\{2,3\})$, $(\{1,3\},\{2,3\})$. The extended concept of Silva and Zhu (2013) is applicable to the overlapping coalitional structures in that it is employed over the union of the overlapping bilateral coalitions; namely the set $\{1,2,3\}$. Consider, for example, the coalitional structure $(\{1,2\},\{1,3\})$. The Nash equilibrium for this structure is coalition-proof if and only if there is no individual nor collective incentive to deviate; that is, player 1 has no incentive to exit either coalition, and players 2 and 3 have no incentives to exit their respective coalitions in order to stand alone or to form the bilateral coalition $\{2,3\}$. The latter is one of the possible self-enforcing sub-coalitions that can be produced from the set $\{1,2,3\}$.

The game considered here is a strategic network formation game (see, e.g., Furusawa and Konishi (2011)). We follow Furusawa and Konishi (2011) in formulating a multistage game, in which the first stage is a participation stage. When transfers are prohibited, the game contains two stages: following the participation stage, there is a contribution stage. When transfers are allowed within coalitions, the game also includes a third stage in which transfers are made. Formally, the participation stage can be described as follows. For a game where $N=\{1,2,3\}$, a pointing game Γ is a list $\left(N,(S_i)_{i\in N},U_i\right)$, where $S_i=\{0,1\}^{N\setminus\{i\}}=\{0,1\}\times\{0,1\}$ for each $i\in N$ (a representative element $s_i=\{s_{ij},s_{ik}\}\in S_i$ describes the countries that country i is pointing towards to initiate an agreement, and $s_{ij}=1$ means that country i selects country j while $s_{ij}=0$ means that country i does not select country j) and $U_i(s_i,s_{-i})=u_i\left(\{i,j\}\subset N: s_{ij}=s_{ji}=1\right)$ for each $i\in N$. For $N=\{1,2,3,....,Z\}$, where $Z\geq 4$, and multiple coalitions $\{T_1,T_2,...,T_K\}$, let $S_i=\{0,1,2,...\}$ and $T_k(s)=\{W\subseteq N: i\in T \Leftrightarrow s_i=k\}$ for all $k=\{1,2,...\}$. As in Furusawa and Konishi (2011), the equilibrium concept is perfectly coalition-proof Nash equilibrium (PCPNE).

Results

We show that if transfers are not allowed, knowledge spillovers flow freely within agreements but research collaborators do not internalize externalities. One important result is that a nation that stands alone in an isolated bilateral arrangement necessarily enjoys an equilibrium payoff that is lower than the common equilibrium payoff earned by the bilateral research collaborators. Even though the stand-alone nation “free rides” on the emission reductions produced by the bilateral research collaborators, it does not partake on the benefits produced by R&D sharing. When transfers are allowed within agreements, they align the incentives of research collaborators: research collaborators find it desirable to choose green R&D products that internalize both types of positive externalities. In contrast to the important result mentioned above, a nation that stands alone in an isolated bilateral arrangement now enjoys an equilibrium payoff that is higher than the common equilibrium payoff earned by the bilateral collaborators. The reason for this is that the benefits from free riding enjoyed by the stand-alone nation outweigh the benefits produced by R&D sharing. Conditional on whether transfers are allowed within agreements, one obtains significantly different equilibrium payoff rankings and stability results for large economies. Hence, the perfectly coalition-proof Nash equilibria also vary conditional on whether transfers are allowed or not.

Conclusions

The findings depend on whether or not transfers are allowed within coalitions. If transfers are allowed, we find that the size of a stable multilateral agreement increases as the size of the global economy expands in the absence of attrition. We also demonstrate that for positive attrition rates all types of coalition structures can be stable as the size of the global economy expands. However, a stable agreement will never involve full participation. On the other hand, if transfers are not allowed, the stable agreement will involve all nations in the globe provided the attrition rate is small enough. Several other arrangements, with participation of almost all nations in the globe, are shown to be stable depending on the value of the attrition rate. Our findings enable us to conjecture that the current international green R&D networks may be self-enforcing and may still increase in size, in spite of the great likelihood that they are characterized by significant attrition.

References

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