From individual welfare to global equity: reforming International Environmental Agreements

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Extended abstract

This study aims to examine the problem of achieving International Environmental Agreements (IEAs), focusing on some normative properties.
Most environmental issues, from the over-exploitation of common resources to global warming, are of common and global interest and require international cooperation. Solving environmental problems, indeed, requires the effort of all countries to act together in order to create mechanisms for protecting and safeguarding the Earth.
Over the last few decades, the problem of designing and building IEAs has been tackled in several ways and from various perspectives. By its nature, the problem is well suited to being treated and studied through a game theory approach [2]. Each country, indeed, chooses whether or not to sign an environmental agreement on a voluntary basis. No external constraints or supranational institutions are in place to force cooperation, influence decisions, or impose any kind of restrictions. Moreover, any decision made by a country has effects on the well-being of all other states.
Several contributions have investigated the problem of building IEAs from

which no country has an incentive to withdraw. Each one uses through different mechanisms, such as punishment schemes for non-cooperative countries, transfer rules to incentivize cooperation, issue linkage, and the inclusion of social externalities.
Our study aims to extend the analysis initiated in [1], further examining the impact of introducing normative properties related to the absence of envy in the formation of environmental agreements.
We consider n asymmetric countries of the world, each producing goods and services. We assume that a degree of well-being and a positive quantity of pollution are related to each production level.
On the one hand, we suppose that individual benefit levels depend solely on private productivity. On the other hand, the level of production of each country contributes to environmental damage impacting all states. Consequently, the costs incurred by each agent are assumed to be a function of the aggregate production levels. Each player makes her own decisions on how much to produce, considering a cost-benefit analysis, meaning that she acts by maximizing her own utility function, expressed as the difference between the benefit and the cost functions. We define an *economic scenario* as a vector whose components represent the level of production of the corresponding country.
As previously observed, there is no higher entity dictating restrictions on production or pushing for cooperation. Each player operates freely, and the countries concerned with environmental protection seek stable cooperation. In other words, in order to safeguard the environment, agents try to conclude a self-enforcing agreement, meaning that no signatory country has an incentive to withdraw, and all non-signatories have no incentive to join the coalition. According to the standard rule, agents in a coalition act as a single player with the aim of maximizing their joint utility function. Simultaneously, players outside the coalition solve their own optimization problems.
Following the *envy-freeness* notion due to [3] and adapted to our framework in [1], we say that, given an economic scenario $\underline{y}$, a coalesced agent is envious at $\underline{y}$ if she achieves a higher level of welfare through a different economic scenario that leaves costs unchanged and generates for her the same level of emissions generated for another agent in the coalition from $\underline{y}$.
Starting from the above definition, each player compares her level of production with that of any other country to which she is related, without considering whether and how much better she is than many other in the coalition. This means that she can judge as non-equitable, because disadvantageous for her, economic scenarios in which the level of production of most others would ensure her a lower benefit. In order to avoid this distortion, we consider a suitable modification of the *per-capita envy-freeness* and *average envy-freeness* notions. Following the idea of per-capita envy-freeness intro-

duced in [4], we say that, given an economic scenario $\underline{y}$, an agent is *per-capita envious* at $\underline{y}$ if she prefers to $\underline{y}$ a different economic scenario that leaves costs unchanged and assigns her a level of production generating an emission level equal to the average of the emissions released by all members of the coalition she belongs to. In a similar manner, we extend to our model the average envy-freeness concept introduced in [5]. More precisely, we say that, given an economic scenario $\underline{y}$, an agent is *average envious* at $\underline{y}$ if she prefers to $\underline{y}$ a different economic scenario that leaves costs unchanged and assigns her a level of production generating an emission level equal to the average of the emissions released by all other members of the coalition she belongs to.
Analyzing the economic scenario resulting from standard cooperation, we find that not for all games Nash equilibria pass the per-capita or average envy-freeness test. Moreover, we determine conditions under which cooperation guarantees at least one of the two absence-of-envy properties. Subsequently, we introduce two new cooperation rules, according to which coalesced players maximize the joint utility function subject to the constraint imposing absence of envy.
The investigation carried out into two-player games shows that games where standard cooperation generates per-capita envy can be divided into three classes. In the first one, the constraint of no envy in the maximization problem generates an economic scenario that provides for equal sharing of total emissions. Furthermore, the total emissions coincide with the aggregate emissions that would occur in the economic scenario resulting from standard cooperation. In the second one, the per-capita envy-free requirement induces economic scenarios in which cooperation protects the environment more than non-cooperation. In the third one, under per-capita absence of envy, the first player is led to lower her level of production, while the second raises her own. The first player's emissions level reduction is not enough to compensate for the second player's emissions level increase. This results in greater environmental damage compared to non-cooperation.
In order to avoid environmental damage, we add a constraint in the maximization problem, imposing suitable total emissions caps. Assuming as a cap the aggregate of emissions generated by standard cooperation, we obtain interesting results. The most significant one concerns the family of games for which the solution of the equilibrium problem subject to the per-capita envy-freeness constraint differs from standard cooperation and equal sharing of total emissions. More precisely, this family of games splits into two different groups. In the first case, the agents produce in such a way that the aggregate emissions are equally shared. In the second case, the first player is willing to reduce her production level and the welfare level she would have with standard cooperation, allowing the second player to increase her production and utility levels. Hence, we can state that, similarly to the envy-

freeness constraint, requiring per-capita absence of envy ensures a balance of production among agents.
The analysis extends to a numerical study for a set composed of ten countries. Findings indicate that, although self-enforcing agreements are limited to those involving coalitions of small-size, introducing equity significantly expands the number of stable cooperations compared to the standard problem.

Keywords
International environmental agreements; Coalition formation rule; Equity; Non-cooperative games.

Area: Game Theory, Optimization.

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