An Evolutionary approach to International Environmental Agreements

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I. Introduction

From the last meeting arranged in Copenhagen on December 2013, it appears difficult to achieve an agreement on efficient, fair, and enforceable reductions of greenhouse gas emissions only at international level. Anthropogenic climate change is an example of social dilemma: despite the global benefits of reducing CO2 emissions, no individual has any incentive to reduce her own emissions, moreover the absence of any supranational force should lead to free-riding behavior. At least this is the classical framework in which completely informed rational agents should operate (Barrett, 1999). However, despite the declared intention of limiting CO2 emissions, there is a progressive increase in the yearly air pollution. What happens when the economic structure is explicitly taken into account? Why nations often fail to respect international agreements? This paper offers a novel theoretical framework to model the game of reducing global greenhouse gas emissions.

It is proposed a novel approach, through a "two-step" procedure, under which integrating both the microeconomic dynamics, originated by agents' economic choices, and the macro economic impact due to the international bargaining. In "Game 1" we model an Evolutionary Game where each country, considered as an "isolated" economy, achieves a different degree of green production depending on the interaction and strategies of both consumers and firms. Afterwards, in "Game 2", each nation bargains the level of environmental standards, to avoid damages due to polluting production, in an International Environmental Agreements (IEA) Static Game. It seems that the definition of an *unique* international environmental standard, though high, is a *weak policy* that alone is not able, in most of the cases, to un-lock a polluting production convention. Our paper confirms that the IEA, if not backed up by a variety of efforts at national, regional, and local levels, are not guaranteed to work well (Ostrom 2010).

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II. Mathematical Model

Let a **two-step** procedure which integrates the results from two games (Γ_1 and Γ_2), the former at national-scale level and the latter at the global level (IEA). Γ_1 shows the "initial conditions" of "isolated" economies in which, due to the economic structure, it is established a certain percentage of **green** production. Afterwards each nation includes this information when bargaining with the other countries in Γ_2.

Consider a normal-form game with a player set composed by individuals that comprise 2 populations, namely households (H) and firms (F). Each population split in clubs depending on the strategy agents play. Strategies are in correspondence with the clubs and are divided into playing environmental friendly (E) or polluting (P). By following Weibull (1998) it is possible to get a simplified version in which the payoffs are obtained by subtracting the main diagonal from the out-of-diagonal entries, that is:

Players	F_E (β)	F_p (1 - β)
H_E (α)	h_E , f_E	0 , 0
H_P (1 - α)	0 , 0	h_P , f_P

Table 1: Normal form game Γ_1.

For simplicity we identify 4 kinds of countries structured along two axes: environmental consciousness (δ) and economic performance (π), which can be either high or low. Their combination reflects the North-South dichotomy between rich and poor countries but it adds the possibility to be green also in low-income regions, as showed in Figure 1.

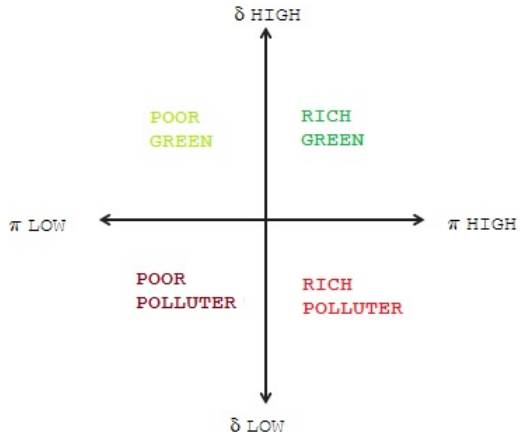

Figure 1: The four categories of countries in this study.

In designing the IEA game we assume that each country i has a welfare objective function ($W_i = B_i - D_i$) given by the difference between the industrial profits, proxy for the benefits B_i, and the costs or damages due to the pollution. We assume a one-to-one relationship between production and emissions. Each nation suffers from the global emissions (D_i) of CO_2 because it could accelerate an adverse Climate Change. Given the evolutionary foundation of country's

economic structure, we do not interpret the country "as if" it was an individual, but it may fail to respect the treatise due to the economic structure rather than to a deliberatively choice to free-ride (Chayes and Chayes (1991, p. 311)). In the IEA game, each country proposes an environmental standard, then all the signatories agree over a **uniform** international environmental standard (θ^*), which establishes the minimum share of green production in each country (that is a carbon-cap policy).

II. Preliminary Results

Our model is able to catch several complex dynamics depending on the values assumed by the three main parameters (δ, π, θ). As an example we show a case of "*locked*" country, to wit a country that is not able to make a green transition due to its economic structure and not because it wants to behave as a free-rider. In this case is more efficacious a change at low-scale level (δ or π) rather than imposing exogenous stringent environmental standards. For instance a poor country, with low environmental consciousness (d), is not able to escape from a polluting production convention only through exogenous policies (S). Based on our simulations, a reduction of 30% of CO2, notwithstanding the full compliance of the treatise, is still not sufficient to guarantee a green transition if not backed up by local initiatives to make people more environmentally aware (Figure 2). Moreover investments in green technologies are necessary to speed up a green development.

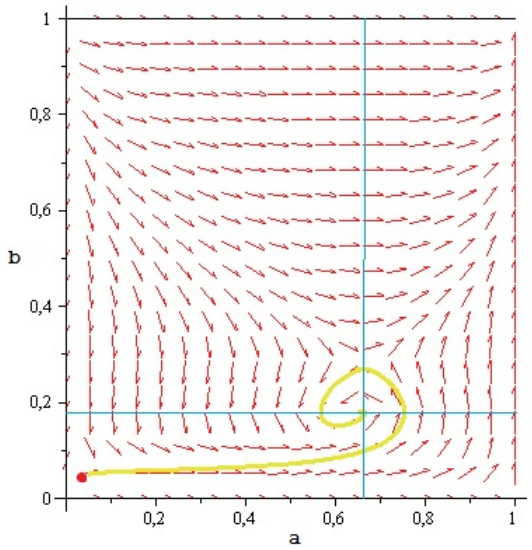

Figure 2: Evolutionary dynamic of a Poor country.

Surprisingly it seems that the definition of θ^* is a weak policy that alone is not able, in several cases, to un-lock a polluting production convention. Furthermore it will be assessed under which conditions the countries are able to overcome historical inequalities to make possible the transition towards an ecologically sustainable development.