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Altruistic Foreign Aid and Climate Change Mitigation

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Abstract

This paper considers one altruistic developed country and several heterogeneous developing countries. We demonstrate that the lack of coordination between countries in tackling climate change finds an optimal solution if developing countries can expect to receive development aid transfers from the developed country. The mechanism requires a sufficiently high level of altruism and specific timing, but a global coalition is not necessary. We also show that the developed country may democratically assign a delegate who is more altruistic than its median voter in order to benefit from the efficiency gain generated by positive development aid transfers.

Keywords Altruism · Climate change · Development aid · International policies · Public good

JEL Classification D62 · D64 · F35 · F53 · Q54

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1 Introduction

In a world of rising inequalities and climate change, development and environmental policies are of crucial importance and represent a major challenge for governmental and international institutions. Combating climate change requires effort and coordination from all countries, even if they differ in terms of wealth. The public-good aspect of pollution emissions abatement means that coordination failures typically lead to insufficient abatement. Moreover, emissions reduction efforts are extremely demanding for developing countries, which face several other challenges such as health, education, and peace. Ambitious development policies are hence a prerequisite if the poorest countries are to have the capacity to implement environmental policies. Yet, development and environmental policies are often considered separately. The United Nations, for example, splits its activities into two separate initiatives: the United Nations Development Programme and the United Nations Environment Programme. Only in recent years have attempts been made to link the two aspects, as seen in the Poverty-Environment Initiative, launched by the United Nations to connect its Development and Environment Programmes, for instance.

The current paper emphasizes the value of addressing both environmental and development objectives within a single framework. In particular, we show that the well-designed interconnection of development and environmental policies can help to solve coordination problems between developed and developing countries. Although the mechanism at play requires a specifically timed decision process, it does not require a global coalition since countries do not have to collectively negotiate the emission abatement levels of each individual country. We also reveal that developed countries may benefit, even from a purely selfish point of view, from being (more) altruistic thanks to the efficiency gain generated by development aid transfers.

Our model comprises one developed country (representing a partial coalition composed of developed countries) and several heterogeneous developing countries. All countries are assumed to be concerned about their own wealth and total emissions abatement. In addition, the developed country is altruistic and hence cares about the welfare of the developing countries. Countries fail to properly internalize the benefits of their emissions abatement to other countries, which typically generates inefficient abatement decisions. By assuming a partial coalition composed of developed countries rather than several developed countries, we limit our focus to the coordination problem between this partial coalition of developed countries and multiple developing countries.

This paper shows that the coordination problem finds a simple solution if developing countries can expect to receive altruistic development aid transfers from the developed country. Each developing country anticipates that making a sub-optimal abatement effort will eventually lower the transfer it receives from the developed country. Once the endogeneity of development aid transfers is properly taken into account, the best strategy for the developing countries is to abate exactly the socially optimal level. Indeed, this abatement level maximizes global wealth (accounting for the costs and benefits of abatement) and the welfare of each developing country is increasing in global wealth since it is a normal good for the altruistic developed country.

The timing of the decision is central to the mechanism. For incentives to work properly, development aid transfers should be determined after all abatement decisions have been made. In practice, this means that developed countries should not commit to a given amount of aid, but should instead communicate on their degree of altruism, which will determine the transfers they will make once all abatement decisions have been made. The coordination problem is ultimately solved thanks to developing countries' anticipation of the forthcoming development aid transfer.

The mechanism at play in our paper leads to optimal emissions abatement without the need for a global coalition to collectively determine this abatement. Developing countries freely choose their own abatement but have incentives to abate optimally thanks to ex post altruistic transfers.

A key restriction of this result is that it only holds if the developed country is altruistic enough to make positive development aid transfers to the developing countries. Since countries can freely decide how much to give to others but not how much to take from others, altruistic transfers are constrained to be positive. If the altruism of the developed country is sufficiently high, the developing countries, anticipating that they will receive aid contingent on their abatement, will choose efficient abatement levels. Conversely, if there is insufficient altruism, the developing countries will anticipate a lack of aid and will choose inefficiently low abatement levels. Interestingly, we show that for intermediate altruism levels, efficient and inefficient equilibria may co-exist, featuring positive and null transfers, respectively.

An additional result of our paper is that the developed country could gain in behaving more altruistically, since providing positive aid solves the coordination problem. We highlight this aspect in an extension of our model featuring a strategic delegation setting where the developed country is composed of individuals who differ in their degree of altruism. In this setting, individuals have to democratically select a representative agent who will choose the abatement levels and aid transfers. In a set of cases, we show that the selected representative agent is more altruistic than the median agent.

The current paper contributes to several strands of literature. First, it contributes to the literature on the provision of global public goods in general, and climate change mitigation in particular. As highlighted in the literature review of Buchholz and Sandler (2021), a key specificity in the problem of global public good provision is that the agents involved are sovereign countries (i.e., there is no global governance). Thus, the provision of global public goods relies on voluntary provision (e.g., Bergstrom 1986; Cornes and Sandler 1984; Cornes and Sandler 1985) or on the organization of formal coalitions through international treaties, for instance (e.g., Barrett 1994; Carraro and Siniscalco 1993; Hoel 1992). The main take-away from this literature is the under-provision of global public goods, whether through voluntary provision or formal coalitions. However, it has been shown that this provision may be increased via different aspects, such as technological change and uncertainty (e.g., Barrett 2006; Boucher and Bramoullé 2010), countries heterogeneity and side payments (e.g., Barrett 2001; McGinty 2007), or social preferences such as altruism, fairness, or reciprocity (e.g., Buchholz et al. 2018; Nyborg 2018; Lange and Vogt 2003; van der Pol et al. 2012). Unlike these papers, in which the improvement of global public good provision is usually shown through a change in the organization of formal coalitions, the mechanism we propose allows us to solve the coordination problem without requiring formal cooperation. Given the practical difficulties of negotiating with a large number of countries, it is worth highlighting that an optimal outcome can be attained by giving the right incentives for the provision of global public goods to countries outside a formal coalition.

Second, our paper contributes to the literature on international development aid. Alesina and Dollar (2000), and Dudley and Montmarquette (1976) show empirically that donors are driven by several motives, such as altruism, historical links, or geopolitical considerations. Azam and Laffont (2003), Epstein and Gang (2009), Hagen (2006), Pedersen (1996, 2001), and Svensson (2000) discuss the efficiency of international aid. These papers take into account the fact that donor countries allocate aid to recipient countries' governments and not directly to the poor, which generates inefficiencies. Unlike this literature, our model does not consider transfer intermediation and induced inefficiencies, but instead brings international environmental issues to the discussion on development aid transfers. We show that competition for foreign aid among recipients can reduce negative externalities instead of exacerbating inefficiencies.

Third, the extension of our model featuring a strategic delegation setting contributes to the literature on strategic delegation in the provision of a public good, and more specifically to the case of a global public good such as climate change mitigation. This literature assumes that a country is composed of individuals who differ with respect to a key attribute (e.g., altruism or environmental sensitivity). It then investigates whether individuals designate a delegate who resembles them or whether they pick a delegate who is more or less endowed with respect to the attribute. In other words, does delegation lead to an over- or under-provision of the public good? Although Besley and Coate (2003) establish an over-provision of public goods, Dur and Roelfsema (2005) and Lorz and Willmann (2005) come to the opposite conclusion. Buchholz et al. (2005) and Rota-Graziosi (2009) examine global public goods and international environmental treaties, finding that respondents assign a delegate who is less "environmentally friendly" than they are. We obtain the opposite result. A detailed comparison of our paper and the latter two articles is provided in Sect. 6.

Finally, our paper is related to the literature on household behavior, and more specifically the "Rotten Kid Theorem" introduced by Becker (1974), which relates to the impact of altruistic transfers in sequential games. We further detail the connection to the Rotten Kid Theorem and its related literature at the end of Sect. 4.

The remainder of the paper is structured as follows. Section 2 presents our modeling assumptions with $n + 1$ countries. In Sect. 3, we determine the Pareto optimal allocations. Section 4 analyzes the interaction between abatement and transfer decisions and compares two decision processes: simultaneous and sequential decisions. In the context of two countries, Sect. 5 further details the impact of altruism on abatement and transfer decisions and Sect. 6 examines the chosen degree of altruism in a political economy setting. Section 7 concludes.

2 Setting

We consider $n + 1$ countries indexed by $i \in \{0, \dots, n\}$. Each country $i \in \{0, \dots, n\}$ has exogenous wealth $w_i \in \mathbb{R}_+$ and emits greenhouse gases (GHG), which generate global pollution. Countries can abate an amount $a_i \in [0, a_i^{max}]$ of GHG emissions at a cost of $c_i(a_i) \geq 0$. The function $a_i \mapsto c_i(a_i)$ is twice continuously differentiable, non-decreasing, and strictly convex, $c_i(0) = 0$ and $c_i(a_i^{max}) \leq w_i$. We denote the vector of emissions abatement by $\boldsymbol{a} = (a_0, \dots, a_n)$. The total amount of emissions abatement is $A = \sum_{i=0}^{n} a_i$, which benefits all countries. More precisely, each country $i \in \{0, \dots, n\}$ is assumed to obtain a benefit $b_i(A) \geq 0$ from global emissions abatement, where the function $b_i(.)$ is twice continuously differentiable, non-decreasing, and concave, with $b_i(0) = 0$. We also assume that $c_i'(0) = 0$ and $c_i'(a_i^{max}) \geq \sum_{j=0}^{n} b_j'(a_i^{max})$ to avoid strictly binding solutions for a_i in our models. In order to provide an interesting context with some externalities, we finally assume that $b_i(.)$ is strictly increasing for $i = 0$ or for at least one $i \neq 0$ when $n \geq 2$.

Country 0 differs from the others by being altruistic. This may lead country 0 to transfer an amount m_i to country i. We denote the vector of transfers paid by country 0 by

$\boldsymbol{m} = (m_1, \dots, m_n)$ and the aggregate level of transfers by $M = \sum_{i=1}^{n} m_i$. For the sake of simplicity, we will generally use the adjective "developed" to refer to country 0 and the adjective "developing" to refer to countries $1, \dots, n$, although our analysis does not require us to make formal assumptions about the distribution of w_i. Note, moreover, that the term "country" is used generically and is not required to correspond to its standard political definition. In particular, country 0 may be viewed as a coalition of developed countries.

For any $i \in \{0, \dots, n\}$, we call w_i the wealth without any abatement, $g_i = w_i - c_i(a_i) + b_i(A)$ the wealth with abatement cost and benefit, and $h_i = w_i - c_i(a_i) + b_i(A) + m_i$ the wealth with abatement cost and benefit plus transfer (with $m_0 = -M$ here). A combination of abatement decisions and transfers is said to be *feasible* if all countries have a non-negative wealth with cost and benefit plus transfer (i.e., $h_i \geq 0$ for all i).

The developed country is altruistic and derives a utility:

$$U_0 = u_0\big(w_0 - c_0(a_0) + b_0(A) - M\big) + \sum_{i=1}^{n} \lambda_i u_i\big(w_i - c_i(a_i) + b_i(A) + m_i\big), \tag{1}$$

where the weight $\lambda_i \geq 0$ determines the degree of altruism that country 0 has for country i. The functions u_0 and u_i are assumed to be strictly increasing, strictly concave, and twice continuously differentiable, and to have a derivative that tends to infinity when wealth tends to zero (this avoids corner solutions, where some countries would end up with zero wealth). The developing countries ($i \in \{1, \dots, n\}$) are selfish and derive a utility:[1]

$$U_i = u_i\big(w_i - c_i(a_i) + b_i(A) + m_i\big). \tag{2}$$

The setting described above is one in which a "public good" (aggregate abatement) is individually provisioned (through individual abatement activities). As we are interested in discussing the inefficiency of decision processes, we start by characterizing the set of Pareto optimal allocations.

3 Pareto Optimal Allocations

The notion of Pareto optimality is standard and does not need to be introduced. Proposition 1 shows that all Pareto optimal allocations are characterized by the same emissions abatement vector. Pareto optimal allocations therefore only differ by the distribution of wealth across all countries. This distribution must, in any case, be such that the developed country could not be made better off by increasing its transfer to a developing country. Formally:

Proposition 1 *A feasible pair $(\boldsymbol{a}, \boldsymbol{m})$ of abatement and transfer vectors achieves a Pareto optimal allocation if and only if*:

[1] Since utility functions are defined up to a monotonic transformation, we could have used any increasing function (instead of u_i) to represent the preferences of the developing country i. However, it slightly simplifies the mathematical analysis to introduce u_i in equation (2), so that both countries 0 and i use the same utility scale to measure the welfare of country i.

1. $\boldsymbol{a} = \boldsymbol{a}^{opt}$, *where* $\boldsymbol{a}^{opt}$ *is the unique solution of*:

$$\sum_{j=0}^{n} b_j'(A) = c_i'(a_i) \ \text{ for } i \in \{0, \dots, n\}, \tag{3}$$

and:

2. $\boldsymbol{m}$ *is any vector of transfers such that for all* $i \in \{1, \dots, n\}$:

$$u_0'\left(w_0 - c_0(a_0^{opt}) + b_0(A^{opt}) - \sum_{j=1}^{n} m_j \right) \geq \lambda_i u_i'\big(w_i - c_i(a_i^{opt}) + b_i(A^{opt}) + m_i\big). \tag{4}$$

Proof See Appendix A.1. □

The optimal abatement levels are such that the effects of each country's abatement on all other countries are internalized. The Pareto optimal allocations all feature the same abatement allocation that maximizes aggregate wealth, but they have different transfer allocations. The fact that all Pareto optimal allocations involve the same abatement levels directly results from the assumption that wealth, abatement costs, and benefits are perfect substitutes. The result cannot be generalized to settings where the utility of country i would be a more complex function of w_i, a_i, and A. Such general frameworks are unfortunately relatively intractable, not to mention the calibration issues involved. Our simplified setting has the advantage of providing a simple understanding of the sub-optimalities that can result from non-cooperative decision processes.

Among all the Pareto optimal allocations, one is preferred by the developed country and is denoted $(\boldsymbol{a}^{opt}, \boldsymbol{m}^{opt})$. Formally, $\boldsymbol{m}^{opt}$ is the vector of transfers such that for all $i \in \{1, \dots, n\}$:

$$u_0'\left(w_0 - c_0(a_0^{opt}) + b_0(A^{opt}) - \sum_{j=1}^{n} m_j^{opt} \right) = \lambda_i u_i'\big(w_i - c_i(a_i^{opt}) + b_i(A^{opt}) + m_i^{opt}\big). \tag{5}$$

In addition, we denote, by definition, $m_0^{opt} = -M^{opt} = -\sum_{i=1}^{n} m_i^{opt}$. For any $i \in \{0, \dots, n\}$, we denote by $g_i^{opt} = w_i - c_i(a_i^{opt}) + b_i(A^{opt})$ the wealth with Pareto optimal abatement and by $h_i^{opt} = w_i - c_i(a_i^{opt}) + b_i(A^{opt}) + m_i^{opt}$ the wealth with Pareto optimal abatement and the transfers preferred by the developed country.

It is noteworthy that some Pareto optimal allocations, including the one preferred by the developed country, may require some negative transfers, when resources flow from developing countries to the developed country. In the following, we will constrain transfers to be non-negative, reflecting the fact that the developed country cannot decide to take resources from the developing countries.

4 Comparison of Two Different Choice Models

In the next step, we compare two decision processes and the outcomes they generate. In the first, the "simultaneous choice model", abatement and transfer decisions are made simultaneously, generating a Nash equilibrium. In the second, the "sequential choice model", all countries initially determine the level of abatement, implementing a Nash equilibrium, and then, in a second stage, the developed country determines the level of transfers. In this sequential choice model, decisions made in the first stage correctly account for what will happen in the second stage.

The two decision processes we consider use the concept of a Nash equilibrium and thus potentially yield sub-optimal allocation. We indeed find that sub-optimality is systematic with one of these decision processes (the "simultaneous choice model" described in Sect. 4.1), although this is not the case with the other (the "sequential choice model" presented in Sect. 4.2). We hence show that one way of avoiding the sub-optimalities that typically arise in a Nash equilibrium with public good provision is to choose an appropriate sequence of abatement and transfer decisions.

4.1 Simultaneous Choice Model

The first decision process we consider is one where abatement and transfer decisions are taken simultaneously. The outcome is assumed to form a Nash equilibrium. We use the subscript "*sim*" to refer to the outcome of the simultaneous decision model. The developed country takes the abatement levels $(a_1^{sim}, \dots, a_n^{sim})$ of the developing countries as given, and chooses abatement a_0^{sim} and transfers $\boldsymbol{m}^{sim}$ to maximize its utility:

$$\begin{aligned}(a_0^{sim}, cm^{sim}) &= \arg\max_{a_0,m} u_0\left(w_0 - c_0(a_0) + b_0(A) - \textstyle\sum_{k=1}^n m_k\right) + \textstyle\sum_{i=1}^n \lambda_i U_i \text{s.t. } A \\ &= a_0 + \textstyle\sum_{k=1}^n a_k^{sim};\ m_i \geq 0\ \forall i \in \{1, \dots, n\};\ U_i \\ &= u_i\left(w_i - c_i(a_i^{sim}) + b_i(A) + m_i\right)\ \forall i \in \{1, \dots, n\}.\end{aligned} \tag{6}$$

A developing country $i \in \{1, \dots, n\}$ takes the transfer m_i^{sim} and abatement levels a_j^{sim} for $j \neq i$ as given and chooses its own abatement to maximize its utility:

$$\begin{aligned}a_i^{sim} &= \arg\max_{a_i} u_i\left(w_i - c_i(a_i) + b_i(A) + m_i^{sim}\right)\text{s.t. } A \\ &= a_i + \textstyle\sum_{\substack{j=0 \\ j\neq i}}^n a_j^{sim}.\end{aligned} \tag{7}$$

A Nash equilibrium is obtained when equations (6) and (7) hold simultaneously. Such an equilibrium has the following property:

Proposition 2 *In the simultaneous choice model, an equilibrium is not Pareto optimal. Aggregate abatement is strictly lower than at the optimum* ($\sum_{i=0}^n a_i^{sim} < \sum_{i=0}^n a_i^{opt}$). *If all transfers are strictly positive* (*i.e.*, $m_i^{sim} > 0$ *for all* $i \in \{1, \dots, n\}$), *the abatement of the developed country is strictly larger than at the optimum* ($a_0^{sim} > a_0^{opt}$).

Proof See Appendix A.2. □

Proposition 2 shows that the simultaneous choice model yields an inefficiently low level of abatement. This reflects the fact that a Nash equilibrium typically provides a sub-optimal provision of public goods. Interestingly, we see that when the developed country is wealthy and altruistic enough to provide positive transfers to developing countries, its own abatement level is above the level it needs to be at the optimum. The sub-optimality is therefore double-faceted. First, there is a low aggregate level of abatement, which generates a level of pollution higher than at the optimum. Second, this aggregate abatement is obtained through a mis-allocation of individual abatements, with too much abatement by the developed country and too little by the developing countries.

4.2 Sequential Choice Model

We now consider a two-stage decision process. In the first stage, all countries choose their emissions abatement simultaneously, determining an abatement vector $\boldsymbol{a}^{seq}$ that solves a Nash equilibrium. The subscript "*seq*" is used to refer to the outcome of the sequential decision model. In the second stage, the developed country determines the transfers $\boldsymbol{m}^{seq}$. Importantly, all countries anticipate the second stage of the decision process when choosing their level of abatement $\boldsymbol{a}^{seq}$ in the first stage. The decision process can be formalized using a standard backward induction presentation:

Stage 2: In the second stage, the developed country takes the abatement vector $\boldsymbol{a}^{seq}$ decided in the first stage as given and chooses the transfer vector $\boldsymbol{m}^{seq}$ to maximize its utility:

$$\begin{aligned} m^{seq} &= \arg\max_m u_0\big(w_0 - c_0(a_0) + b_0(A^{seq}) - \textstyle\sum_{k=1}^n m_k\big) + \sum_{i=1}^n \lambda_i U_i \text{s.t. } A^{seq} \\ &= \textstyle\sum_{k=0}^n a_k^{seq};\ m_i \geq 0\ \forall i \in \{1, \dots, n\}; U_i \\ &= u_i\big(w_i - c_i(a_i^{seq}) + b_i(A^{seq}) + m_i\big)\ \forall i \in \{1, \dots, n\}. \end{aligned} \tag{8}$$

This optimization problem yields a reaction function $\boldsymbol{a}^{seq} \mapsto \boldsymbol{m}^{seq}(\boldsymbol{a}^{seq})$. Note that the lower the available wealth of a developing country, $w_i - c_i(a_i^{seq}) + b_i(A^{seq})$, the more aid the developed country will transfer to the latter.

Stage 1: In this first stage, all countries simultaneously choose their abatement levels, anticipating that altruistic transfers will adjust to abatement decisions through the function $\boldsymbol{a}^{seq} \mapsto \boldsymbol{m}^{seq}(\boldsymbol{a}^{seq})$. The developed country takes the abatement levels $(a_1^{seq}, \dots, a_n^{seq})$ of the developing countries as given, and implements a level of abatement provided by:

$$\begin{aligned} a_0^{seq} &= \arg\max_{a_0} u_0\big(w_0 - c_0(a_0) + b_0(A) - \textstyle\sum_{k=1}^n m_k^{seq}(a)\big) + \sum_{i=1}^n \lambda_i U_i \text{s.t. } A \\ &= a_0 + \textstyle\sum_{k=1}^n a_k^{seq};\ a = (a_0, a_1^{seq}, \dots, a_n^{seq}); U_i \\ &= u_i\big(w_i - c_i(a_i^{seq}) + b_i(A) + m_i^{seq}(a)\big)\ \forall i \in \{1, \dots, n\}. \end{aligned} \tag{9}$$

The developing country $i \in \{1, \dots, n\}$ takes abatement a_j^{seq}, for $j \neq i$, as given, and implements a level of abatement provided by:

$$\begin{aligned} a_i^{seq} &= \arg\max_{a_i} u_i\big(w_i - c_i(a_i) + b_i(A) + m_i^{seq}(ca)\big) \text{s.t. } A \\ &= a_i + \textstyle\sum_{\substack{j=0 \\ j\neq i}}^n a_j^{seq};\ a \\ &= (a_0^{seq}, \dots, a_i, \dots, a_n^{seq}). \end{aligned} \tag{10}$$

A Nash equilibrium is obtained when Eqs. (9) and (10) hold simultaneously. We can state two results that contrast with the result of the simultaneous choice model. The first one is:

Proposition 3 *In the sequential choice model, if all transfers are strictly positive at an equilibrium, the allocation is the Pareto optimal allocation preferred by the developed country* ($i.e.$, $m_i^{seq} > 0$ *for all* $i \in \{1, \dots, n\} \Rightarrow \{\boldsymbol{a}^{seq} = \boldsymbol{a}^{opt}$ *and* $\boldsymbol{m}^{seq} = \boldsymbol{m}^{opt}\}$).

Proof See Appendix A.3. □

Proposition 3 is closely connected to the "Rotten Kid Theorem", which considers one agent ("the donor") who cares about other agents ("the recipients"). The Rotten Kid Theorem states that if the donor makes positive wealth transfers to all recipients after the latter have taken their chosen actions, then it is in the interest of all recipients to pursue measures that maximize the utility of the donor, thereby solving externality issues. This theorem was first shown by Becker (1974) and further investigated by Bergstrom (1989) and Cornes and Silva (1999) in the field of household behavior (in which the donor and the recipients are "the household head" and "the kids", respectively). It has also already been applied in the context of environmental externalities with a federal government as the donor and regional governments as the recipients (Caplan and Silva 1999; Silva and Caplan 1997; Nagase and Silva 2000). Our analytical framework, however, differs slightly from the framework in these papers. In the Rotten Kid Theorem, all the recipients play first and the donor only plays after. In our model, all countries, including the developed country, determine their abatement at the same time. The donor is thus assumed to make a decision from the first stage of the game.

A key property required for Proposition 3 to hold is that of transferable utilities, as emphasized in Bergstrom (1989) for the Rotten Kid Theorem. When this assumption does not hold, inefficiencies may appear even in the absence of any externalities, since the recipients have an incentive to squander resources in order to obtain additional transfers. This effect, called the "Samaritan's dilemma", was first introduced by Buchanan (1975) and further investigated by Bruce and Waldman (1990), Dijkstra (2007), and Lindbeck and Weibull (1988). In our setting, the Samaritan's dilemma is avoided since abatement costs, abatement benefits, and wealth are assumed to be perfect substitutes. While this assumption may appear reasonable if we see abatement costs and benefits as variations in production levels, it would no longer be the case if we introduced other forms of benefits, such as changes in health and mortality. This is certainly a limitation of our analysis, although it is also found in most of the literature on international environmental policies.

Our second result concerns the existence of a Pareto optimal equilibrium, a topic less frequently discussed in the literature:

Proposition 4 *In the sequential choice model, the Pareto optimal allocation preferred by the developed country (i.e.,* $\{\boldsymbol{a}^{opt}, \boldsymbol{m}^{opt}\}$*) is an equilibrium if and only if* $m_i^{opt} \geq 0$ *and* $m_i^{opt} \geq c_i(a_i^{opt}) - c_i(\tilde{a}_i) - (b_i(A^{opt}) - b_i(\tilde{a}_i + \sum_{j \neq i} a_j^{opt}))$ *for all* $i \in \{1, \ldots, n\}$*, in which* $\tilde{a}_i$ *is defined such that* $c_i'(\tilde{a}_i) = b_i'(\tilde{a}_i + \sum_{j \neq i} a_j^{opt})$*.*

Proof See Appendix A.4. □

Proposition 4 details the necessary and sufficient conditions under which the Pareto optimal allocation preferred by the developed country is an equilibrium. More specifically, the transfers preferred by the developed country should be non-negative and should at least compensate the developing countries for the cost of their additional effort minus the private benefit they get from it. In concrete terms, this requires to have bound on the wealth and degree of altruism of the developed country, as it will be made clearer in the following section.

5 Full Characterization of Equilibria in a Simple Case

The results provided in Sect. 4 relate to the properties of the equilibria that may be generated by the various interactions we considered. We did not, however, address the technical questions of equilibrium existence, uniqueness, or multiplicity. Such issues are in fact very complex for the sequential choice model, as the non-negativity constraint imposed on altruistic transfers means that the functions $a_i \mapsto m_i^{seq}(a_0^{seq}, \dots, a_i, \dots, a_n^{seq})$ are, in general, not concave (these functions are typically flat and equal to zero for low values of a_i and then positive when a_i is above some threshold). This implies that the maximization problems of developing countries are typically not convex with, in some cases, multiple solutions and thus multiple equilibria. Such complexity may be viewed as a potential hurdle for providing simple complete resolutions of the strategic interactions we consider. However, it is also a source of richness, as we obtain a discontinuous impact of altruism that has so far been overlooked in the literature on the Rotten Kid Theorem.

In this section, we want to emphasize issues related to non-convexity and why this implies equilibrium multiplicity and a discontinuous impact of altruism. To keep the analysis tractable, we focus on a scenario where there is only one developed country and one developing country (which corresponds to the case where $n = 1$) and where the developing country derives no benefit from abatement (i.e., $b_1(.) = 0$). This setting is rich enough to include the main aspects we want to highlight.

In practice, we consider the wealth levels w_0 and w_1 as given and we denote the developed country's degree of altruism by λ and the transfer to the developing country by m. We consider the special case where $b_0(.) \geq 0$ and $b_1(.) = 0$. We discuss the impact of λ on the outcome of the simultaneous and sequential choice models. We first state a result regarding the existence and uniqueness of a Nash equilibrium in the simultaneous choice model, which holds for all values of λ.

Proposition 5 *In the simultaneous choice model with two countries and* $b_1(.) = 0$, *a unique Nash equilibrium exists for all* $\lambda \geq 0$. *The equilibrium is inefficient.*

Proof See Appendix A.5. □

We now state a result regarding the existence and multiplicity of Nash equilibria in the sequential choice model and their properties.

Proposition 6 *In the sequential choice model with two countries and* $b_1(.) = 0$, *a unique pair* $(\underline{\lambda}, \overline{\lambda})$ *exists such that* $\underline{\lambda} < \overline{\lambda}$ *and*:

1. *If* $\lambda < \underline{\lambda}$, *a single Nash equilibrium exists. The equilibrium is inefficient and has a null transfer level.*
2. *If* $\underline{\lambda} \leq \lambda \leq \overline{\lambda}$, *two Nash equilibria exist, an inefficient equilibrium with a null transfer level and an efficient equilibrium with a strictly positive transfer level. The efficient equilibrium Pareto-dominates the inefficient equilibrium.*
3. *If* $\overline{\lambda} < \lambda$, *a single Nash equilibrium exists. The equilibrium is efficient and has a strictly positive transfer level.*

Proof See Appendix A.6. □

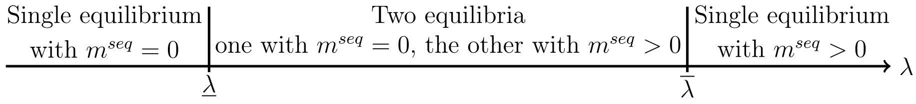

Fig. 1 Equilibria characteristics in function of the degree of altruism in the sequential choice model

The sketch of the proof of Proposition 6 is as follows. First, we show that there are at most two Nash equilibria, one featuring efficient abatements and transfer, and one featuring inefficient abatements and no transfer. Second, we explain how the existence of these equilibria depends on the degree of altruism. When the developing country does not benefit from abatement (i.e., $b_1(.) = 0$), the degree of altruism affects the transfer level but not the abatement levels in both equilibria. The efficient equilibrium exists if and only if the degree of altruism is high enough (i.e., $\lambda \geq \underline{\lambda}$) because high transfer prevents the developing country from moving to lower abatement without transfer. The inefficient equilibrium exists if and only if the degree of altruism is low enough (i.e., $\lambda \leq \bar{\lambda}$) since the perspective of low transfer does not incentivize the developing country to move to higher abatement with transfer. Finally, we show that there is a range of degrees of altruism in which both equilibria exist (i.e., $\underline{\lambda} < \bar{\lambda}$), and that the efficient equilibrium Pareto-dominates the inefficient equilibrium.

Figure 1 summarizes the finding of Proposition 6, indicating which equilibrium (or equilibria) exists depending on the degree of altruism λ. For low levels of altruism ($\lambda < \underline{\lambda}$), the transfer is always equal to zero and there is no gain in announcing that transfers are possible at the second stage. The developing country anticipates that there will be no transfer, and has no incentive to choose the socially optimal abatement level as in the simultaneous choice model. For high levels of altruism ($\lambda > \bar{\lambda}$), the transfer is always strictly positive. The sequential choice model delivers the virtuous outcome described in Proposition 3, as the transfer incentivizes the developing country to choose the socially optimal abatement level. For intermediate levels of altruism ($\underline{\lambda} \leq \lambda \leq \bar{\lambda}$), two equilibria exist, one with transfer and one without. Moreover, both the developed country and the developing country prefer the equilibrium with transfer. Interestingly, this equilibrium multiplicity implies the existence of possible "climate traps", where transfers are null and aggregate abatement is low, despite the fact that a Pareto-dominating equilibrium with positive transfer and higher aggregate abatement could exist. We also see that the outcome will be a discontinuous function of λ, regardless of the equilibrium selection mechanism assumed.

To illustrate Proposition 6, we develop a simple numerical exercise with $u_0(.) = log(.)$, $u_1(.) = log(.)$, $c_0(a_0) = a_0 + 0.05a_0^2$, $c_1(a_1) = 0.1a_1^2$, $b_0(A) = 5A^{0.5}$, $b_1(A) = 0$, $w_0 = 60$, and $w_1 = 20$. Figure 2 displays six figures representing transfer level (m), abatement levels (A, a_0 and a_1), and wealth levels (h_0 and h_1) with respect to the developed country's degree of altruism (λ). Each of the six figures shows two lines, respectively characterizing the inefficient equilibrium (dashed line), which only exists when $\lambda \leq \bar{\lambda}$, and the Pareto optimal equilibrium (solid line), which only exists when $\lambda \geq \underline{\lambda}$. Between $\underline{\lambda}$ and $\bar{\lambda}$, the two Nash equilibria coexist. The top left figure displays the transfer level (m) and shows that the inefficient equilibrium is characterized by the absence of any transfer, while the Pareto optimal equilibrium is characterized by a strictly positive transfer. In the latter case, the more the developed country cares about the developing country, the higher the transfer will be. The top right figure depicts the aggregate abatement level (A). It is higher in the Pareto optimal equilibrium than in the inefficient equilibrium. The middle left and right figures display the abatement levels (a_0 and a_1) of the developed and developing countries, respectively. The

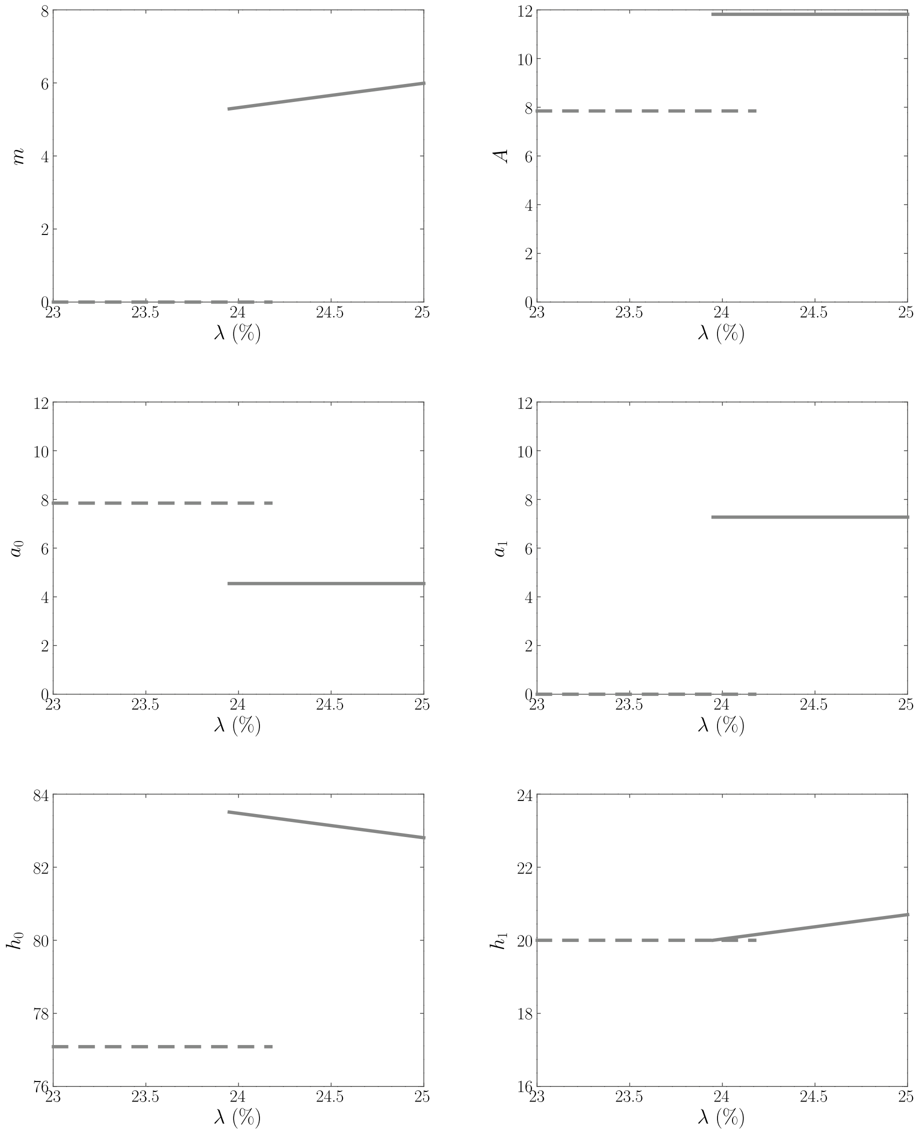

Fig. 2 The impact of the altruism level λ in the sequential choice game with one developed country and one developing country ($n = 1$)

abatement a_1 of the developing country is higher in the Pareto optimal equilibrium than in the inefficient equilibrium (and conversely for the abatement a_0 of the developed country). In the Pareto optimal equilibrium, the developing country internalizes the marginal abatement benefit of the developed country thanks to the operational transfer. The bottom left and right figures depict the wealth level of the developed country (h_0) and the wealth level of the developing country (h_1), respectively. In the efficient equilibrium, the wealth level h_0 of the developed country decreases with altruism, while the wealth level h_1 of the developing country increases with altruism since the transfer m increases with altruism. The interesting aspect is that an increase in λ may force coordination on the efficient equilibrium (the inefficient equilibrium does not exist when $\lambda > \overline{\lambda}$ and is Pareto dominated by the efficient one when $\overline{\lambda} \geq \lambda \geq \underline{\lambda}$). This transition to the efficient equilibrium goes hand in hand with a positive impact on the wealth level of the developed country due to the gains resulting from cooperation. Relatively selfish agents in the developed country may thus be willing to support a policy that assumes a greater degree of altruism than their own preferences. Indeed, they may anticipate that the costs of this additional government generosity will be balanced by gains stemming from the increase in developing countries' abatement levels. Such a mechanism is illustrated below, in the case where λ is decided through a democratic process.

6 Altruism in a Strategic Delegation Setting

We assume that the developed country is composed of agents who exhibit various degrees of altruism and that these agents have to democratically appoint a delegate, characterized by his or her level of altruism λ, who will determine the abatement level and transfer aids. We aim to show that if the government implements the sequential choice model, the delegate's degree of altruism may be higher than that of the median agent. If we view the developed country as representing a partial coalition composed of developed countries, then the agents' appointment of a delegate may be interpreted as the developed countries in the coalition designating their delegate. As in the previous section, we assume that $b_1(.) = 0$. We consider a continuum of agents in the developed country with preferences represented by:

$$U_0^\kappa = u_0\big(w_0 - c_0(a_0) + b_0(A) - m_1\big) + \lambda^\kappa U_1, \tag{11}$$

in which the parameter λ^κ represents the degree of altruism of agent κ. We assume that the distribution of degrees of altruism admits a well-defined (unique) median λ_{med}. Moreover, the (democratic) choice of λ is assumed to be made before both countries decide on emission abatement levels and the developed country chooses the transfer to the developing country. This order implies that the outcome of the sequential choice model remains the same as in the previous section. Moreover, we assume that, in the case of multiple equilibria, the equilibrium selected is always the efficient one. Because agents have different preferences, they generally disagree about the person to whom the choice of abatement and transfer policies should be delegated. We consider the case where the delegate is determined by a democratic process that selects a Condorcet winner - in other words, a degree of altruism that would be preferred over any other degree of altruism in a simple two-alternative majority vote.

Proposition 7 *Consider the case with two countries and $b_1(.) = 0$. Assume that the median degree of agents' altruism in the developed country is $\lambda_{med} < \underline{\lambda}$ and that one agent has a degree of altruism $\underline{\lambda}$, where $\underline{\lambda}$ is the threshold mentioned in Proposition 6. If the choice of λ is made through a democratic process that selects a Condorcet winner before the sequential choice model is played, the Condorcet winner has a degree of altruism $\underline{\lambda}$.*

Proof See Appendix A.7. □

Proposition 7 states that if $\lambda_{med} < \underline{\lambda}$, the level of altruism of the Condorcet winner $\underline{\lambda}$ is strictly greater than that of the median voter λ_{med}. This interesting result is due to the discontinuity of U_0^{κ} at $\underline{\lambda}$, which incentivizes each agent to assign a delegate who is either as altruistic or more altruistic than she is, in order to reap the benefits of achieving the Pareto optimal equilibrium. This result contrasts with those of Buchholz et al. (2005) and Rota-Graziosi (2009), who find that each respondent will assign a delegate who is less "environmentally friendly" than she is. They study delegating to a representative the possibility of bargaining an international environmental agreement. In Buchholz et al. (2005), individuals anticipate that delegating to a more environmentally friendly individual will affect the outcome of the bargaining, and they accordingly designate a less environmentally friendly individual. This result echoes Hoel (1991), who demonstrates that a country that engages in unilateral action as if it were more environmentally friendly than it really is, damages its bargaining position in international agreements. Rota-Graziosi (2009) extends Buchholz et al. (2005)'s result by endogenizing the choice of the delegation rule. Each country seeks to enhance its bargaining position through two channels: the identity of the delegate and the method of delegation that transfers national power to that delegate. Choosing a strong delegation rule is a credible strategic commitment that affects the threat of disagreement and ultimately the negotiated outcome. Rota-Graziosi (2009) also finds that the designated representative will be only marginally environmentally friendly. Our results are different because we do not study the same coordination process in international agreements. While the authors cited study bargaining between countries, we are interested in an original mechanism that solves the coordination problem.

7 Conclusion

This short paper aims to deliver two messages. First, development and environmental policies should be considered together rather than separately. Our result reveals that transfers related to development policies can serve as a coordination device, avoiding the sub-optimalities that arise in the non-cooperative provision of environmental goods. Reaching the Pareto optimal outcomes involves using an appropriate decision-making process, where transfers are determined after pollution abatement levels. Interestingly, the mechanism at play leads to optimal abatement levels without requiring a global agreement. However, the coordination mechanism only works if developed countries are sufficiently wealthy and altruistic, so that positive transfers actually flow from them to developing countries.

The second point is that the efficiency gains generated by being sufficiently altruistic may lead developed countries to democratically delegate decision-making authority to an individual who is more altruistic than the median voter. Furthermore, if the timing of transfer and abatement decisions is appropriately chosen, development policies may receive additional support, as they may help to address global environmental challenges, in particular those related to climate change.

A Appendices

A.1 Proof of Proposition 1

A feasible allocation is Pareto optimal if it maximizes a convex combination of all countries' utilities. Accounting for the fact that country 0 is altruistic, we obtain the result that a feasible allocation is Pareto optimal if $\gamma_i \in [\lambda_i, +\infty[$ exists, for all $i \in \{1, \dots, n\}$, such that:

$$\begin{array}{l} \max_{\boldsymbol{m},\boldsymbol{a}} \ u_0\left(w_0 - c_0(a_0) + b_0(A) - \sum_{k=1}^n m_k\right) + \sum_{j=1}^n \gamma_j u_j\left(w_j - c_j(a_j) + b_j(A) + m_j\right) \\ \text{s.t. } A = \sum_{k=0}^n a_k. \end{array} \tag{12}$$

The first order condition of (12) relative to m_i implies that:

$$u_0'\left(w_0 - c_0(a_0) + b_0(A) - \sum_{k=1}^n m_k\right) \geq \lambda_i u_i'\left(w_i - c_i(a_i) + b_i(A) + m_i\right). \tag{13}$$

The first order conditions of (12) relative to a_0 and a_i ($i \in \{1, \dots, n\}$) are respectively:

$$\sum_{j=0}^n b_j'(A) = c_0'(a_0), \tag{14}$$

$$\sum_{j=0}^n b_j'(A) = c_i'(a_i). \tag{15}$$

This concludes the proof.

A.2 Proof of Proposition 2

The first order condition of (6) relative to m_i gives either:

$$m_i = 0 \quad \text{and} \quad \lambda_i u_i'\left(w_i - c_i(a_i) + b_i(A)\right) < u_0'\left(w_0 - c_0(a_0) + b_0(A) - \sum_{\substack{k=1 \\ k \neq i}}^n m_k\right), \tag{16}$$

or:

$$m_i \geq 0 \quad \text{and} \quad \lambda_i u_i'\left(w_i - c_i(a_i) + b_i(A) + m_i\right) = u_0'\left(w_0 - c_0(a_0) + b_0(A) - \sum_{k=1}^n m_k\right). \tag{17}$$

The first order condition of (6) relative to a_0 and the first order condition of (7) relative to a_i are respectively:

$$\sum_{j=1}^n \lambda_j \frac{u_j'(.)}{u_0'(.)} b_j'(A) + b_0'(A) = c_0'(a_0), \tag{18}$$

$$b_i'(A) = c_i'(a_i). \tag{19}$$

We show by contradiction that $\sum_{i=0}^n a_i^{sim} < \sum_{i=0}^n a_i^{opt}$. Assume that $\sum_{i=0}^n a_i^{sim} \geq \sum_{i=0}^n a_i^{opt}$. Then, (14) and (18) imply $a_0^{sim} \leq a_0^{opt}$ (given that $\lambda_j \frac{u_j'}{u_0'} \leq 1$ in (18)). Moreover, (15) and (19) imply $a_i^{sim} \leq a_i^{opt}$ with strict inequality for at least one i (since $b_j(.)$ is strictly increasing for $j = 0$ or for at least one $j \neq 0$ when $n \geq 2$). Thus, $\sum_{i=0}^n a_i^{sim} < \sum_{i=0}^n a_i^{opt}$, which contradicts our hypothesis, and thus proves the first part of the proposition.

Regarding the second part of the proposition, now assume that none of the m_i are strictly binding in zero, which means that $\lambda_j \frac{u_j'}{u_0'} = 1$ in (18). Given that $\sum_{i=0}^n a_i^{sim} < \sum_{i=0}^n a_i^{opt}$, (14) and (18) imply $a_0^{sim} > a_0^{opt}$.

A.3 Proof of Proposition 3

If all transfers are strictly positive at an equilibrium (i.e., $m_i^{seq} > 0$ for all $i \in \{1, \dots, n\}$), aggregate wealth is shared between countries such that for all $i \in \{1, \dots, n\}$:

$$u_0'\left(w_0 - c_0(a_0^{seq}) + b_0(A^{seq}) - \sum_{j=1}^n m_j^{seq}\right) = \lambda_i u_i'\left(w_i - c_i(a_i^{seq}) + b_i(A^{seq}) + m_i^{seq}\right). \tag{20}$$

Equation (20) implies that an abatement change by one country affects the wealth of all countries the same way (i.e., positively or negatively). Each country thus has incentives to maximize the wealth of all countries or simply the aggregate wealth, which implies that the abatement choices are Pareto optimal (i.e., $\boldsymbol{a}^{seq} = \boldsymbol{a}^{opt}$). Moreover, equation (20) with $\boldsymbol{a}^{seq} = \boldsymbol{a}^{opt}$ gives the Pareto optimal allocation preferred by the developed country (i.e., $\boldsymbol{m}^{seq} = \boldsymbol{m}^{opt}$).

A.4 Proof of Proposition 4

Note that the condition $m_i^{opt} \geq c_i(a_i^{opt}) - c_i(\tilde{a}_i) - (b_i(A^{opt}) - b_i(\tilde{a}_i + \sum_{j \neq i} a_j^{opt}))$, in which $\tilde{a}_i$ is defined such that $c_i'(\tilde{a}_i) = b_i'(\tilde{a}_i + \sum_{j \neq i} a_i^{opt})$, can be rewritten:

$$w_i - c_i(a_i^{opt}) + b_i(A^{opt}) + m_i^{opt} \geq w_i - c_i(\tilde{a}_i) + b_i(\tilde{a}_i + \sum_{j \neq i} a_j^{opt}). \tag{21}$$

Let us first prove the necessary condition. Assume that $\{\boldsymbol{a}^{opt}, \boldsymbol{m}^{opt}\}$ is an equilibrium. Since the developed country can only make positive transfers, $m_i^{opt} \geq 0$ for all $i \in \{1, \dots, n\}$. Moreover, any developing country $i \in \{1, \dots, n\}$ should have no incentive to deviate, which implies Eq. (21).

Let us now prove the sufficient condition. Assume that $m_i^{opt} \geq 0$ and $m_i^{opt} \geq c_i(a_i^{opt}) - c_i(\tilde{a}_i) - (b_i(A^{opt}) - b_i(\tilde{a}_i + \sum_{j \neq i} a_j^{opt}))$ for all $i \in \{1, \dots, n\}$. Consider the allocation $\{\boldsymbol{a}^{opt}, \boldsymbol{m}^{opt}\}$. The developed country has no incentive to deviate since the allocation is its preferred Pareto optimal allocation. Developing countries $i \in \{1, \dots, n\}$ have no incentive to deviate either. If one of them changes its abatement to a level at which it receives no more aid, Eq. (21) shows that it will have lower wealth. Moreover, if it changes its abatement to a level at which it still receives some aid, it decreases the aggregate wealth and thus the share of each country including its own share (since the way of sharing is still determined by the developed country's preference in this case). This finally implies that $\{\boldsymbol{a}^{opt}, \boldsymbol{m}^{opt}\}$ is an equilibrium.

A.5 Proof of Proposition 5

With only one developing country, the first order condition of (6) relative to m states that either $m = 0$ and $\lambda u_1'(.) < u_0'(.)$, or $m \geq 0$ and $\lambda u_1'(.) = u_0'(.)$. Moreover, with $b_1(.)$ null, the first order condition of (6) relative to a_0 and the first order condition of (7) relative to a_1 are, respectively:

$$b_0'(A) = c_0'(a_0), \tag{22}$$

$$0 = c_1'(a_1). \tag{23}$$

Equations (22) and (23) have a unique solution (a_1^{sub}, a_0^{sub}) such that $a_1^{sub} = 0$ and $b_0'(a_0^{sub}) = c_0'(a_0^{sub})$. There is thus a unique Nash equilibrium, i.e., (a_1^{sub}, a_0^{sub}). Moreover, it is inefficient since $b_0'(a_0^{sub}) > c_1'(0)$.

A.6 Proof of Proposition 6

We first show that there are at most two Nash equilibria. With only one developing country, the first order condition of (8) relative to m shows that we have either:

$$m = 0 \quad \text{and} \quad \lambda u_1'\big(w_1 - c_1(a_1)\big) < u_0'\big(w_0 - c_0(a_0) + b_0(A)\big), \tag{24}$$

or:

$$m \geq 0 \quad \text{and} \quad \lambda u_1'\big(w_1 - c_1(a_1) + m\big) = u_0'\big(w_0 - c_0(a_0) + b_0(A) - m\big), \tag{25}$$

which implicitly defines a function $(a_0, a_1, \lambda) \mapsto m^{seq}(a_0, a_1, \lambda)$. Moreover, with $b_1(.)$ null, the first order condition of (9) relative to a_0 and the first order condition of (10) relative to a_1 are, respectively:

$$b_0'(A) = c_0'(a_0), \tag{26}$$

$$\frac{\partial m^{seq}}{\partial a_1} = c_1'(a_1), \tag{27}$$

where $\frac{\partial m^{seq}}{\partial a_1} = 0$ if m^{seq} is binding in 0 and $\frac{\partial m^{seq}}{\partial a_1} = b_0'(A)$ if m^{seq} is not binding in 0. Indeed, the derivative of (25) relative to a_1 gives:

$$\lambda u_1''(.) \cdot \left(-c_1'(a_1) + \frac{\partial m^{seq}}{\partial a_1}\right) = u_0''(.) \cdot \left(b_0'(A) - \frac{\partial m^{seq}}{\partial a_1}\right), \tag{28}$$

which implies $b_0'(A) - \frac{\partial m^{seq}}{\partial a_1} = 0$ thanks to (27). Equations (26) and (27) respectively determine the best response functions $a_0^b(a_1)$ (continuous) and $a_1^b(a_0)$ (discontinuous). In Fig. 3, we represent $a_0^b(a_1)$ and two curves $a_1^I(a_0)$ and $a_1^{II}(a_0)$, associated with $0 = c_1'(a_1)$ and $b_0'(A) = c_1'(a_1)$, respectively. Note that $a_1^I(a_0) < a_1^{II}(a_0)$. Note also that the best response

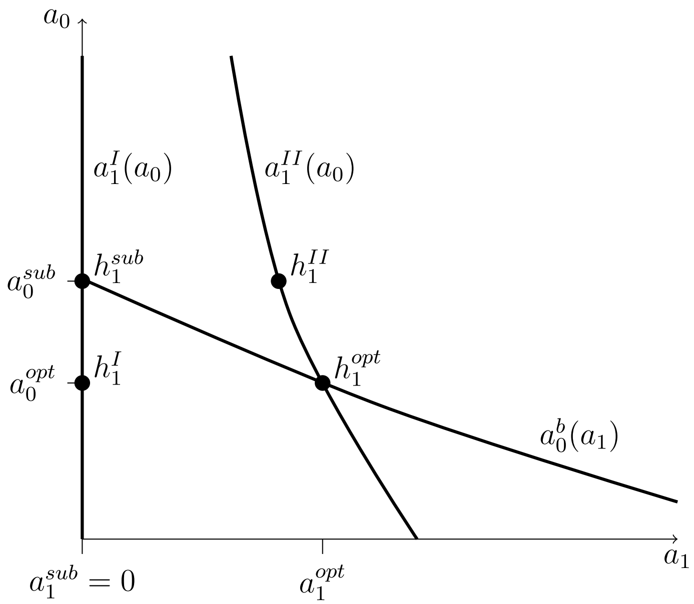

Fig. 3 Abatement best response functions in the sequential choice model with one developing country and $b_1 = 0$

function $a_1^b(a_0)$ is composed partly of $a_1^I(a_0)$ and partly of $a_1^{II}(a_0)$, such that for any a_0, the utility of country 1 is the highest possible. $a_0^b(a_1)$ crosses $a_1^I(a_0)$ once in (a_1^{sub}, a_0^{sub}) such that $a_1^{sub} = 0$ and $b_0'(a_0^{sub}) = c_0'(a_0^{sub})$. $a_0^b(a_1)$ crosses $a_1^{II}(a_0)$ once in (a_1^{opt}, a_0^{opt}) such that $b_0'(a_0^{opt} + a_1^{opt}) = c_0'(a_0^{opt})$ and $b_0'(a_0^{opt} + a_1^{opt}) = c_1'(a_1^{opt})$ because $a_0^b(a_1)$ has a slope larger than -1 while the inverse function of $a_1^{II}(a_0)$ has a slope lower than -1. There are thus at most two Nash equilibria, i.e., (a_1^{sub}, a_0^{sub}) and (a_1^{opt}, a_0^{opt}). (a_1^{sub}, a_0^{sub}) is inefficient since $b_0'(a_0^{sub}) > c_1'(0)$, while (a_1^{opt}, a_0^{opt}) is efficient.

The second part of the proof relates to whether (a_1^{sub}, a_0^{sub}) and (a_1^{opt}, a_0^{opt}) are Nash equilibria or not, depending on λ. For (a_1^{sub}, a_0^{sub}) to be a Nash equilibrium, the best response function $a_1^b(a_0)$ simply has to be $a_1^I(a_0)$ in a_0^{sub}. For (a_1^{opt}, a_0^{opt}) to be a Nash equilibrium, the best response function $a_1^b(a_0)$ simply has to be $a_1^{II}(a_0)$ in a_0^{opt}. In what follows, as represented in Fig. 3, we denote by h_1^{sub}, h_1^{II}, h_1^{opt}, and h_1^I the wealth levels reached by country 1 for abatement (a_1^{sub}, a_0^{sub}), $(a_1^{II}(a_0^{sub}), a_0^{sub})$, (a_1^{opt}, a_0^{opt}), and $(a_1^I(a_0^{opt}), a_0^{opt})$, respectively. Thus, (a_1^{opt}, a_0^{opt}) is a Nash equilibrium if and only if $h_1^{opt} \geq h_1^I$, and (a_1^{sub}, a_0^{sub}) is a Nash equilibrium if and only if $h_1^{sub} \geq h_1^{II}$.

Lemma 1 *There exists a unique* $\underline{\lambda}$ *such that*:

- $h_1^{opt} < h_1^I$ if $\lambda < \underline{\lambda}$,
- $h_1^{opt} > h_1^I$ if $\lambda > \underline{\lambda}$.

Proof $h_1^{opt} = w_1 - c_1(a_1^{opt}) + m^{opt}$ and $h_1^I = w_1 - c_1(a_1^I(a_0^{opt}))$, in which m^{opt} is such that:

$$\lambda u_1'(h_1^{opt}) = u_0'\big(w_0 - c_0(a_0^{opt}) + b_0(A^{opt}) - m^{opt}\big). \tag{29}$$

Since a_0^{opt} and a_1^{opt} do not depend on λ, we have $\frac{dh_1^{opt}}{d\lambda} = \frac{\partial m^{opt}}{\partial \lambda}$ and $\frac{dh_1^I}{d\lambda} = 0$. Computing $\frac{\partial m^{opt}}{\partial \lambda}$ by taking the derivative of (29) relative to λ, we get $\frac{\partial m^{opt}}{\partial \lambda} = \frac{-u_1'}{\lambda u_1'' + u_0''} > 0$. Thus, $\frac{dh_1^{opt}}{d\lambda} > \frac{dh_1^I}{d\lambda}$ and h_1^{opt} crosses h_1^I at most once when λ increases. Moreover, $h_1^{opt} < h_1^I$ for $\lambda = 0$ and $h_1^{opt} > h_1^I$ for $\lambda = +\infty$. Thus, h_1^{opt} crosses h_1^I once when λ increases, which concludes the proof. □

Lemma 1 implies that (a_1^{opt}, a_0^{opt}) is a Nash equilibrium if and only if $\lambda \geq \underline{\lambda}$. Moreover, the transfer level in this Nash equilibrium is $m^{opt} \geq c_1(a_1^{opt}) > 0$.

Lemma 2 *There exists a unique* $\overline{\lambda}$ *such that*:

- $h_1^{sub} > h_1^{II}$ if $\lambda < \overline{\lambda}$,
- $h_1^{sub} < h_1^{II}$ if $\lambda > \overline{\lambda}$.

Proof $h_1^{sub} = w_1 - c_1(a_1^{sub})$ and $h_1^{II} = w_1 - c_1(a_1^{II}(a_0^{sub})) + m^{sub}$, in which m^{sub} is such that:

$$\lambda u_1'(h_1^{II}) = u_0'\big(w_0 - c_0(a_0^{sub}) + b_0(a_1^{II}(a_0^{sub}) + a_0^{sub}) - m^{sub}\big). \tag{30}$$

Since a_0^{sub} and a_1^{sub} do not depend on λ, we have $\frac{dh_1^{sub}}{d\lambda} = 0$ and $\frac{dh_1^{II}}{d\lambda} = \frac{\partial m^{sub}}{\partial \lambda}$. Computing $\frac{\partial m^{sub}}{\partial \lambda}$ by taking the derivative of (30) relative to λ, we get $\frac{\partial m^{sub}}{\partial \lambda} = \frac{-u_1'}{\lambda u_1'' + u_0''} > 0$. Thus, $\frac{dh_1^{sub}}{d\lambda} < \frac{dh_1^{II}}{d\lambda}$ and h_1^{sub} crosses h_1^{II} at most once when λ increases. Moreover, $h_1^{sub} > h_1^{II}$ for $\lambda = 0$ and $h_1^{sub} < h_1^{II}$ for $\lambda = +\infty$. Thus, h_1^{sub} crosses h_1^{II} once when λ increases, which concludes the proof. □

Lemma 2 implies that (a_1^{sub}, a_0^{sub}) is a Nash equilibrium if and only if $\lambda \leq \overline{\lambda}$. Moreover, the transfer level in this Nash equilibrium is null.

Lemma 3 *We have* $\underline{\lambda} < \overline{\lambda}$.

Proof The aggregate wealth is larger in the Pareto optimal allocation (a_0^{opt}, a_1^{opt}) than in $(a_1^{II}(a_0^{sub}), a_0^{sub})$. Since the shares of aggregate wealth are determined by the preference of country 0 in these two allocations, we have $h_1^{II} < h_1^{opt}$. Furthermore, we have $h_1^I = h_1^{sub} = w_1$. Let us now assume that $\overline{\lambda} \leq \underline{\lambda}$. Consider λ such that $\overline{\lambda} \leq \lambda \leq \underline{\lambda}$. With this λ, we have: $h_1^{II} < h_1^{opt} \leq h_1^I = h_1^{sub} \leq h_1^{II}$, which is a contradiction. Thus $\underline{\lambda} < \overline{\lambda}$. □

Lemma 4 $(a_1^{opt}, a_0^{opt}, m^{opt})$ *Pareto dominates* $(a_1^{sub}, a_0^{sub}, 0)$ *for any* $\lambda \in [\underline{\lambda}, \overline{\lambda}]$.

Proof Assume $\lambda \in [\underline{\lambda}, \overline{\lambda}]$. In this case, $h_1^{opt} \geq h_1^I = h_1^{sub}$. Moreover, $u_0'(h_0^{opt}) = \lambda u_1'(h_1^{opt})$ and $u_0'(h_0^{sub}) > \lambda u_1'(h_1^{sub})$ imply $u_0'(h_0^{sub}) > u_0'(h_0^{opt})$ and thus $h_0^{sub} < h_0^{opt}$. This concludes the proof. □

Lemmas 3 and 4 conclude the proof of Proposition 6.

A.7 Proof of Proposition 7

Denoting by λ the delegate's level of altruism, the utility of an agent with altruism level λ^κ is:

$$U_0^\kappa(\lambda) = u_0(h_0^{sub}) + \lambda^\kappa u_1(h_1^{sub}) \text{ if } \lambda < \underline{\lambda}, \tag{31}$$

$$U_0^\kappa(\lambda) = u_0(h_0^{opt}(\lambda)) + \lambda^\kappa u_1(h_1^{opt}(\lambda)) \text{ if } \lambda \geq \underline{\lambda}. \tag{32}$$

Consider an agent with altruism level $\lambda^\kappa \leq \underline{\lambda}$. We have $h_0^{opt}(\underline{\lambda}) \geq h_0^{sub}$ and $h_1^{opt}(\underline{\lambda}) \geq h_1^{sub}$ (see the proof of Lemma 4). Thus, $U_0^\kappa(\underline{\lambda}) \geq U_0^\kappa(\lambda)$ for any $\lambda < \underline{\lambda}$. Moreover, for any $\lambda \geq \underline{\lambda}$, we have $U_0^{\kappa\prime}(\lambda) = (-u_0'(h_0^{opt}(\lambda)) + \lambda^\kappa u_1'(h_1^{opt}(\lambda)))m^{opt\prime}(\lambda)$. Since $u_0'(h_0^{opt}(\lambda)) = \lambda u_1'(h_1^{opt}(\lambda))$, we get $U_0^{\kappa\prime}(\lambda) \leq 0$ and $U_0^\kappa(\underline{\lambda}) \geq U_0^\kappa(\lambda)$ for any $\lambda \geq \underline{\lambda}$. Thus, the preferred altruism level for the agent with altruism level $\lambda^\kappa \leq \underline{\lambda}$ is $\lambda = \underline{\lambda}$. Finally, if the median agent has an altruism level lower than $\underline{\lambda}$ and the delegate is decided by a democratic process that selects a Condorcet winner, the Condorcet winner necessarily has an altruism level $\underline{\lambda}$ since most agents prefer this altruism level to any other.

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