Altruistic Foreign Aid
And Climate Change Mitigation

Antoine Bommier Amélie Goerger Arnaud Goussebaïle
Jean-Philippe Nicolaï *

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Abstract

This paper emphasizes the value of addressing both environmental and development objectives. We consider one altruistic developed country and several heterogeneous developing countries. It is demonstrated that the coordination issue of countries to tackle climate change finds a simple solution when developing countries can expect to receive development aid transfers from the developed country. The timing of decision is central to the mechanism: Development aid transfers should be decided after global pollution is observed. The main restriction of our result is that it only holds if the developed country is altruistic enough to make positive development aid transfers to developing countries. Nevertheless, even from a purely selfish point of view, it is profitable for the developed country to implement an altruistic policy – which leads to higher welfare for all countries.
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*Bommier: ETH Zurich, abommier@ethz.ch; Goerger: ETH Zurich, agoerger@ethz.ch; Goussebaïle: ETH Zurich, agoussebaile@ethz.ch; Nicolaï: ETH Zurich, jnicolai@ethz.ch

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 efforts from all countries, even if some differ in terms of wealth, and coordination between them. The public-good aspect of emissions abatement is such that coordination failure typically leads to an insufficient amount of pollution reduction. Moreover, emission reduction efforts are extremely demanding for developing countries, which face several other challenges such as peace, education and health. Ambitious development policies are hence a prerequisite for the poorest countries to have the capacity to implement environmental policies. Nonetheless, development and environmental policies are often thought of separately. As such, the United Nations devote two of its most important programmes to development and environmental issues, with the United Nations Development Programme on the one hand and the United Nations Environment Programme on the other hand. In the United States, development and environmental affairs are delegated to two powerful independent agencies, the US Agency for International Development and the Environmental Protection Agency. In recent years, there are initiatives that attempt to link the two aspects. For instance, the United Nations launched the Poverty-Environment Initiative to connect its Development and Environment Programmes, and the World Bank Group, whose objective is to promote the development of countries, announced on the 3rd of December 2018 during the 2018 United Nations Climate Change Conference that it would invest 200 billion of US dollars to support countries taking action against climate change from 2021-25. In this vein, the current paper emphasizes the value of addressing both environmental and development objectives in a single framework. In particular, it is shown that a well-designed interconnection of development and environmental policies can help to solve coordination problems between developed and developing countries.

In the model we develop, there is one developed country and several heterogeneous developing countries. All the countries are assumed to be concerned about their own consumption and the sum of all emissions abatement. Furthermore, the developed country cares also for the welfare of the developing countries. Countries fail to properly internalize the benefits that their emissions abatement have on the other countries. When the environmental dimension is considered in isolation, coordination has proved being very difficult to achieve, with significant problems of information asymmetry resulting from the inability to accurately observe other countries' environmental efforts and associated costs. The difficulties that countries had in agreeing on a level of emission reductions during the various rounds of United Nations Climate Change Conferences highlight this coordination problem.

The main result of the paper shows that the coordination issue finds a simple solution when developing countries can expect to receive development aid transfers from the developed country. Indeed, even though developing countries do not care for the welfare of the other countries, they anticipate that making sub-optimal environmental efforts will lower the amount of transfers they will receive from the developed country through two effects. Firstly, the developed country would be more affected by pollution and then would decide to make greater abatement, leaving fewer resources for development-aid purposes. Secondly, other developing countries would be more affected by pollution, leading to a smaller share of the development-aid for developing countries making sub-optimal environmental efforts. Once the endogeneity of development aid transfers is properly taken into account, the best strategy of the developing countries involves abating exactly the socially optimal level. This provides them with the best combination of monetary transfers and environmental benefits.

The timing of decision is central to the mechanism. For incentives to work properly, development aid transfers should be decided after global pollution is observed. In practice, this means that developed countries should not commit to a given amount of aid at climate negotiations, but to a given degree of altruism which will determine the transfers they will make later on, once aggregate abatement is observed. An interesting aspect of the mechanism is that there is no need to observe each country's abatement effort, cost or benefit. Global pollution and country specific consumption levels are sufficient information for the developed country, while global pollution and aggregate benefit function are sufficient information for developing countries. The anticipation of forthcoming development aid transfer allows therefore to solve the coordination problem in spite of information asymmetry.

The main restriction of our result is that it holds only if the developed country is altruistic enough to make positive development aid transfers to developing countries. Otherwise, developing countries anticipate that they will not receive development aid and therefore tend to reduce their efforts. This is of course a serious problem in today's world where key players are more inclined to reduce their transfer to developing countries. As we will explain, however, the altruistic policy may be profitable even from a purely selfish point of view. In other words, exhibiting altruistic preferences can be used as a strategic device by the developed country to generate efficiency gains, which will be shared among all countries.

To our best knowledge, there is no paper that is particularly close to ours. Nevertheless, the current paper contributes to several strands of literature such as environmental economics and development economics, and more specifically to the literature that is at the intersection of the two (for instance, Chambers and Jensen (2002), Bretschger and Vinogradova (2015), Hamdi-Cherif et al. (2011)). The paper also connects to the literature on household behavior, and more specifically the Rotten Kid theorem, introduced by Becker (1974), more broadly investigated by Bergstrom (1989).

The remainder of the paper is structured as follows. Section 2 presents the modeling assumptions. In Section 3, the Pareto optimal allocations are determined. Section 4 analyzes the interaction between abatement and transfer decisions and compares two decision processes: simultaneous and sequential decisions. Section 5 examines how our results depend on altruism. Finally, Section 6 concludes.

2 Setting

We consider $n + 1$ countries indexed by $i \in \{0, .., n\}$. Each country $i \in \{0, .., n\}$ has an exogenous endowment $w_i \in \mathbb{R}_+$ and emits GHG emissions, which generate global pollution. They can abate an amount $a_i \in \mathbb{R}_+$ of GHG emissions at a cost $c_i(a_i)$. The function $a_i \to c(a_i)$ is increasing and convex, with $c(0) = 0$. We denote by $\boldsymbol{a} = (a_0, \cdots, a_n)$ the vector of emissions abatement. The total amount of emissions abatement is $A = \sum_{i=0}^{n} a_i$ which benefits to all country. More precisely, each country $i \in \{0, \cdots, n\}$ is assumed to obtain a benefit $b_i(A)$ from global emissions abatement, where the function $b_i(.)$ is increasing and concave, with $b_i'(\infty) = 0$.

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 by $\boldsymbol{m} = (m_1, \cdots, m_n)$ the vector of transfers paid by country 0 and by $M = \sum_{i=1}^{n} m_i$ the aggregate level of transfers. For simplicity sake, we will generally use the adjective "developed" to refer to country 0 and the adjective "developing" to refer to countries $1, \cdots, n$, even though our analysis does not require to make formal assumptions about the distribution of the w_i.

The developing countries ($i \in \{1, .., n\}$) are selfish and derive a utility

$$U_{_i} = u_i \left(w_i - c_i(a_i) + b_i(A) + m_i \right), \tag{1}$$

where the function u_i is increasing and concave. The developed country is altruistic and derives a utility

$$U_0 = u_0 \left(w_0 - c_0(a_0) + b_0(A) - M \right) + \sum_{i=1}^{n} \lambda_i U_i, \tag{2}$$

where the U_i are the utilities of the developing countries detailed in equation (1). The weight $\lambda_i \geq 0$ determines the degree of altruism that country 0 has for country i. The function u_0 is an increasing and concave function. For technical convenience all utility, cost and benefit functions (i.e. the u_i, c_i and b_i) are assumed to be twice continuously differentiable.

The setting described above is one with a "public good" (aggregate abatement) which is individually provisioned (through individual abatement activities). For the model to be fully specified, one has to assume some structure of decision process. We will in fact consider two decision processes and compare the outcomes they provide. In the first one, called "simultaneous choice model", abatement and transfers decisions are taken simultaneously, generating a Nash-equilibrium. In the second one, called "sequential choice model", all the countries decide first the level of abatement, solving a Nash equilibrium, and in a second stage the developed country decides the level of transfers. Decisions taken in the first stage properly account for what will happen in the second stage. As we are interested in discussing how inefficient these decision processes may be, 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 vector of emissions abatement. Therefore, Pareto optimal allocations only differ by the distribution of wealth across all countries. However, this distribution has in any case to be such that consumption is non-negative in any country and the developed country could not be made better off by increasing its transfer to a developing country. Formally:

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

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

$$\sum_{j=0}^{n} b_j'(A) = c_i'(a_i) \quad \textit{for } i \in \{0, \cdots, n\},$$

and:

2. $\boldsymbol{m}$ *is any vector of transfers such that:*

$$\sum_{j=1}^{n} m_j \leq w_0 - c_0(a_0^{opt}) + b_0(A^{opt})$$

and for all $i \in \{1, \cdots n\}$ *:*

$$w_i - c_i(a_i^{opt}) + b_i(A^{opt}) + m_i \geq 0,$$
$$u_0'\Big(w_0 - c_0(a_0^{opt}) + b_0(A^{opt}) - \sum_{j=1}^{n} m_j\Big) \geq \lambda_i u_i'\Big(w_i - c_i(a_i^{opt}) + b_i(A^{opt}) + m_i\Big).$$

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 fact that all Pareto optimal allocations involve the same abatement levels directly results from the assumption that wealth, abatement costs and benefits are perfect substitute. The result would not generalize to settings where the utility of country i would be a more complex function of w_i, a_i and A. Such most general frameworks are unfortunately quite intractable - without mentioning calibration issues. Our simplified setting has the advantage of providing a simple understanding of the sub-optimalities that can result from non-cooperative decision processes.

It is noteworthy that achieving optimality may require to have transfer 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. This non-negativity constraint on transfers will create a potential source of inefficiency that will add to the other sources of inefficiencies we consider, and in particular to those related to the decision processes that we explore in the following section.

4 Interaction between aid and abatement decisions

We now compare two decision processes which, as they both use the concept of a Nash equilibrium, may yield on sub-optimal allocations. We find that sub-optimality is systematic with one of these decision processes (the "simultaneous choice model" considered in Section 4.1), while this is not the case with the other (the "sequential choice model" considered in Section 4.2). Hence, we show that a way to avoid the sub-optimalities that typically arise in a Nash equilibrium with a public good 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 we will use the subscript "sim" to refer to the outcome of the simultaneous decision model. Formally, the developed country takes the abatement levels $(a_1^{sim}, \cdots a_n^{sim})$ of the developing countries as given, and choose abatement a_0^{sim} and transfers $\boldsymbol{m}^{sim}$, to maximize its utility:

$$\begin{aligned}(a_0^{sim}, \boldsymbol{m}^{sim}) = \arg\max_{\boldsymbol{m}, a_0} \; & u_0\Big(w_0 - c_0(a_0) + b_0(A) - \sum_{k=1}^{n} m_k\Big) + \sum_{i=1}^{n} \lambda_i U_i \\ \text{s.t.} \;\; & A = a_0 + \sum_{k=i}^{n} a_k^{sim}; \quad m_j \geq 0; \\ & U_i = u_i\Big(w_i - c_i(a_i^{sim}) + b_i(A) + m_i\Big).\end{aligned} \tag{3}$$

A developing country $i \in \{1, \cdots, n\}$ 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 welfare:

$$\begin{aligned}a_i^{sim} = \arg\max_{a_i} \; & u_i\Big(w_i - c_i(a_i) + b_i(A) + m_i^{sim}\Big) \\ \text{s.t.} \;\; & A = a_i + \sum_{\substack{j=0 \\ j \neq i}}^{n} a_j^{sim}.\end{aligned} \tag{4}$$

A Nash equilibrium is obtained when equations (3) and (4) simultaneously hold. The existence and the uniqueness will be discussed in Section 5 (case with one developing country).

Proposition 2 *In the simultaneous choice model, aggregate abatement is strictly lower than in the Pareto optimal allocations ($\sum_{i=0}^{n} a_i^{sim} < \sum_{i=0}^{n} a_i^{opt}$).*

Moreover, in the case where transfers are not strictly binding in 0 *(i.e. when $m_i^{sim} > 0$ for all i), 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 that a Nash equilibrium typically provides a sub-optimal provision of public good. 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 what it should do at the optimum. The sub-optimality is therefore double-faceted. First, there is a low aggregate level of abatement involving 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.

A way to restore optimality would be to allow a form of contracting where each transfer given to a developing country (m_i) is conditional to its level of abatement (a_i).[1] This would however require that the developed country could observe the individual abatement a_i and has a perfect knowledge on both the cost functions $a_i \to c_i(a_i)$ and the benefit functions $A \to b_i(A)$. This is of course questionable. Moreover, committing to an allocation rule can be particularly costly. The sequential game we develop below aims at solving the sub-optimality without requiring the observability of individual abatement decisions, abatement costs and benefits, and without committing to an allocation rule.

4.2 Sequential choice model

We now consider a two-stage decision process. In the first stage, all the countries choose their emissions abatement simultaneously, determining a vector of abatement $\boldsymbol{a}^{seq}$ which solves a Nash equilibrium. In the second stage, the developed country

[1] An ongoing debate in the development economics literature has been engaged regarding whether foreign aid should be conditional to developing countries' efforts. For instance, Svensson (2000) and Svensson (2003), analyze whether it is efficient and feasible to implement conditional aid, without considering environmental issues.

observes the aggregate level of abatement $A^{seq} = \sum_{i=0}^{n} a_i^{seq}$, as well as the available wealth of the developing countries, that is the amount $w_i - c_i(a_i^{seq}) + b_i(A^{seq})$, and decides of the transfers $\boldsymbol{m}^{seq}$. Importantly, all countries anticipate the second stage of the decision process when they choose their level of abatement $\boldsymbol{a}^{seq}$ at the first stage. The decision process can be formalized as follows:

Stage 2: At this stage, the developed country takes the vector abatement $\boldsymbol{a}^{seq}$ as given and chooses the vector of transfers $\boldsymbol{m}^{seq}$ to maximize its utility;

$$\begin{aligned} \boldsymbol{m}^{seq} &= \arg\max_{\boldsymbol{m}} \; u_0\Big(w_0 - c_0(a_0) + b_0(A^{seq}) - \sum_{k=1}^{n} m_k\Big) + \sum_{i=1}^{n} \lambda_i U_i \\ &\text{s.t.} \quad A^{seq} = \sum_{i=0}^{n} a_i^{seq}; \quad m_i \geq 0; \\ &U_i = u_i\Big(w_i - c_i(a_i^{seq}) + b_i(A^{seq}) + m_i\Big). \end{aligned} \tag{5}$$

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

Stage 1: At Stage 1, all countries simultaneously choose their abatement levels, anticipating that altruistic transfers will adjust to abatement decisions through the function $\boldsymbol{a}^{seq} \to \boldsymbol{m}^{seq}(\boldsymbol{a}^{seq})$. The developed country's abatement is given by :

$$\begin{aligned} a_0^{seq} &= \arg\max_{a_0} \; u_0\Big(w_0 - c_0(a_0) + b_0(A) - \sum_{i=1}^{n} m_i^{seq}(\boldsymbol{a})\Big) + \sum_{j=1}^{n} \lambda_i U_i \\ &\text{s.t.} \quad A = a_0 + \sum_{i=1}^{n} a_i^{seq}; \quad \boldsymbol{a} = (a_0, a_1^{seq}, \cdots, a_n^{seq}); \\ &U_i = u_i\Big(w_i - c_i(a_i^{seq}) + b_i(A) + m_i^{seq}(\boldsymbol{a})\Big). \end{aligned} \tag{6}$$

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

$$\begin{aligned} a_i^{seq} &= \arg\max_{a_i} \; u_i\Big(w_i - c_i(a_i) + b_i(A) + m_i^{seq}(\boldsymbol{a})\Big) \\ &\text{s.t.} \quad A = a_i + \sum_{\substack{j=0 \\ j \neq i}}^{n} a_j^{seq}; \quad \boldsymbol{a} = (a_0^{seq}, \cdots, a_i, \cdots, a_n^{seq}). \end{aligned} \tag{7}$$

A Nash equilibrium is obtained when equations (6) and (7) hold simultaneously. The existence and the uniqueness will also be discussed in Section 5. Resolution of the sequential choice model is quite involved. In particular one has to pay attention that the non-negativity constraint imposed on transfers has the consequence that the functions $a_i \to m_i^{seq}(a_0^{seq}, \cdots, a_i, \cdots, a_n^{seq})$ 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 in turn implies that the problems of developing countries are typically not convex, with in some cases multiple solutions. The impact of these non-convexities will be further investigated in Section 5. We can however readily state an important result, that holds when all transfers are positive.

Proposition 3 *In the sequential choice model, if all transfers are strictly positive then the allocation is Pareto optimal (i.e.* $m_i^{seq} > 0$ *for all* $i \Rightarrow \boldsymbol{a}^{seq} = \boldsymbol{a}^{opt}$*).*

Proof. See Appendix A.3. ■

Proposition 3 shows that even if all the countries are engaged in a non-cooperative game of public good provision (abatement decisions follow from a Nash equilibrium), altruistic transfers may play the role of a coordinating device, providing a Pareto-efficient outcome. The outcome obtained in this sequential model is actually the one that the developed country would choose if it could have perfect knowledge on all abatement cost and benefit functions, and decide about all actions (including the abatement of developing countries). What is remarkable, though, is that the sequential choice model is able to implement such outcome, without having symmetric information on cost and benefit functions, and without constraining developing countries in their abatement decisions. The developed country only needs to know its own cost and benefit functions, and must be able to observe the aggregate abatement $\sum_{i=1}^{n} a_i^{seq}$ and the available wealth (the $w_i - c_i(a_i^{seq}) + b_i(A^{seq})$) of each developing country. This is much less restrictive than imposing knowledge of the a_i and the functions $c_i(.)$ and $b_i(.)$. The endowments w_i typically reflect production abilities, with abatement costs and benefits directly impacting the production activities. Abatement may consist in using less polluting and more costly inputs, while "climate benefits" may directly impact the production with, for example, fewer interruptions, capital destruction and crop damage resulting from extreme events. Observing $w_i - c_i(a_i^{seq}) + b_i(A^{seq})$ involves observing actual production outcomes, which is much easier than to observe abatement choices, and their related costs and benefits. In addition to their own cost and benefit functions, developing countries need to know that the developed country is wealthy and altruistic enough to make strictly positive transfers. Developing countries also need to know the aggregate benefit function and must be able to observe aggregate abatement in order to anticipate the transfer they will receive.

From a theoretical point of view, Proposition 3 can be seen as an application of the Rotten Kid theorem, initially introduced by Becker (1974) in a specific setting and more broadly investigated by Bergstrom (1989). The Rotten Kid theorem states that, if a head of household cares about other household members and can reallocate wealth across household members, then it is in the interest of any household members to take measures that maximize total household utility. Our analytical framework differs from the latter in two aspects. First, in the Rotten Kid theorem, the household head can reallocate wealth across household members in any direction, while here the developed country can only transfer some of its private wealth towards developing countries, which implies that transfers might be binding in 0. Secondly, in the Rotten Kid theorem, all the household members play first except the household head who plays second. Here the developed country chooses the abatement at the same time as the developing countries but decides the transfer later on. These two differences with the Rotten Kid theorem generate multiple solutions. We know from Bergstrom (1989) that a key property required for the Rotten Kid theorem to hold is that of transferable utilities, which in our setting comes from the assumption that wealth, costs and benefits are perfect substitute. While this assumption could seem reasonable if we see abatement costs and benefits as variation on production levels, it would no longer be the case if one introduces other forms of benefits, like changes in health and mortality. This is certainly an important limit of the analysis, a limit which however concerns most of the economics literature on climate change. Cornes and Silva (1999) demonstrate that the Rotten Kid theorem also holds in the absence of transferable utility if the externalities are assumed to take the form of a specific public good, such that the total quantity of the public good is the sum of individual contributions. In the case of climate change, countries make abatement whose costs are non linear, which means that the total quantity of the public good is not the sum of individual contributions.

A second restriction of Proposition 3 is that it only bears on the case where the transfers m_i^{seq} are strictly positive. One may be concerned that this does not reflect today's reality where transfers remain limited and not exclusively motivated by altruistic purpose.[2] Although this source of concern is definitely legitimate, especially in a period where altruistic policies seem to loose in popularity, we explain below why our framework could provide an argument for exhibiting altruistic motives.

5 Considerations on altruism

In this Section, we aim to explain the effects of exhibiting greater or weaker degrees of altruism. In order to simplify the analysis we focus on the case where there is only one developed and one developing country (that corresponds to the case where $n = 1$). Most of the insights would actually extend to the case where there are many countries at play, though the analysis would be much more cumbersome. Indeed, instead of having a single source of non-convexity, there would be n of them.

In all the sequel we consider the wealth levels w_0 and w_1 as given and we note λ_1 the degree of altruism of the developed country. We discuss the impact of λ_1 on the outcome of the sequential and simultaneous choice model. First, we state a result about the existence of a Nash equilibrium in the simultaneous choice model.

Proposition 4 *In the simultaneous choice model with two countries, there exists a single Nash equilibrium.*

Proof. See Appendix A.4. ■

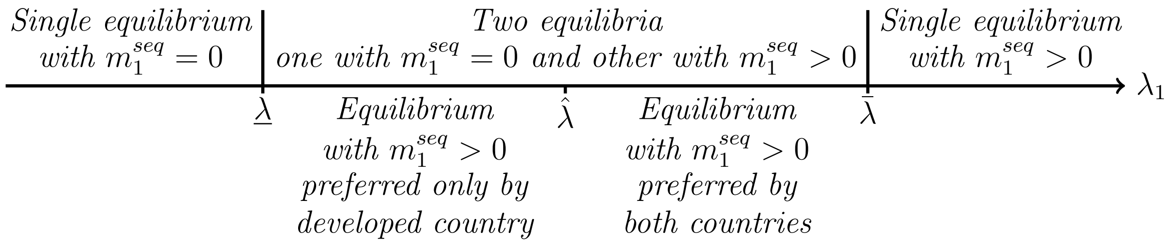
We now state a result about the existence of a Nash equilibrium in the sequential choice model and its properties.

Proposition 5 *In the sequential choice model with two countries (and some technical conditions detailed in appendix A.5), there exist $\underline{\lambda} < \hat{\lambda} < \bar{\lambda}$, such that:*

1. *If $\lambda_1 < \underline{\lambda}$ there exists a single Nash equilibrium and the transfer level is $m_1^{seq} = 0$.*
2. *If $\underline{\lambda} \leq \lambda_1 \leq \bar{\lambda}$ there are two Nash equilibria, one equilibrium such that the transfer level is $m_1^{seq} = 0$ and the other one such that $m_1^{seq} > 0$.*
3. *If $\bar{\lambda} < \lambda_1$ there exists a single Nash equilibrium and the transfer level is $m_1^{seq} > 0$.*

[2]According to Alesina and Dollar (2000), donors are driven by several motives, such as altruism, past history or geographical proximity.

Moreover, if $\underline{\lambda} \leq \lambda_1 < \hat{\lambda}$*, the Nash equilibrium with* $m_1^{seq} > 0$ *is preferred by the developed country to the Nash equilibrium with* $m_1^{seq} = 0$*, but this is not the case for the developing country. If* $\hat{\lambda} \leq \lambda_1 \leq \bar{\lambda}$*, the Nash equilibrium with* $m_1^{seq} > 0$ *Pareto-dominates the Nash equilibrium with* $m_1^{seq} = 0$*.*



Proof. See Appendix A.5. ■

Proposition 5 clarifies how the level of transfer depends on the degree of altruism. For low levels of altruism ($\lambda_1 < \underline{\lambda}$), the transfer is always equal to zero and there is no gain in announcing the potentiality of transfers 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 ($\lambda_1 > \bar{\lambda}$), 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 ($\underline{\lambda} < \lambda_1 < \bar{\lambda}$), two equilibria exist, one with and one without transfer. Moreover, the developed country always prefers the equilibrium with transfer, while the preference of the developing country depends on the level of altruism. When λ_1 is below $\hat{\lambda}$, the developing country prefers the equilibrium without transfer and each equilibrium might emerge. When λ_1 is above $\hat{\lambda}$, the developing country prefers the equilibrium with transfer, which implies that this equilibrium Pareto dominates the one without transfer. In this case, if both countries are rational and know that the other is also rational, they will both choose the abatement level corresponding to the equilibrium with transfer.

Our result highlights how increasing the degree of altruism can help countries to move from the inefficient equilibrium without transfer to the Pareto optimal equilibrium with transfer. If we are stuck in the inefficient equilibrium without transfer and we increase the level of altruism λ_1, the shift to the Pareto optimal equilibrium occurs when λ_1 crosses the threshold $\hat{\lambda}$, leading to a significant efficiency gain. Comparing the efficient and inefficient Nash equilibria that exist when $\lambda_1 = \hat{\lambda}$, we see that all utility gains are attributed to the developed country as the utility of the developing country remains the same. This means that if the true degree of altruism of the developed country is below $\hat{\lambda}$, it may be in its own interest to behave as if its degree of altruism were just above $\hat{\lambda}$. In other words, "exhibiting altruistic preferences" can be used as a strategic device by the developed country to generate efficiency gains from which it privately gains. A further increase of altruism enables to better share the efficiency gains between the developed country and the developing country.

To illustrate Proposition 5 we develop a simple numerical exercise. The specification is detailed in Appendix A.6. Figure 1 displays five figures representing the transfer level (m_1), the abatement levels (a_0 and a_1) and the utility levels (U_0 and U_1) with respect to the degree of altruism (λ_1) of the developed country. On each of the five figures, there are two lines characterizing on the one hand the existence of the inefficient equilibrium for $\lambda \leq \bar{\lambda}$ and on the other hand the existence of the Pareto optimal equilibrium for $\lambda \geq \underline{\lambda}$. Between $\underline{\lambda}$ and $\bar{\lambda}$ where the two Nash equilibria coexist, the two lines are represented in dash. Figure 1a displays the transfer level (m_1) and shows that the inefficient equilibrium is characterized by the absence of 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 is the transfer. Figures 1b and 1c depict the abatement levels (a_0 and a_1) of the developed country and the developing country respectively. In the inefficient equilibrium, an increase of altruism drives the developed country to further internalize the marginal abatement benefit of the developing country, which leads to the increase of abatement a_0 by the developed country and as a consequence the decrease of abatement a_1 by the developing country by free-riding. On the other hand, in the Pareto optimal equilibrium, an increase of altruism does not affect abatement levels as all Pareto optimal allocations involve the same abatement levels. Moreover, the abatement a_1 of the developing country is higher in the Pareto optimal equilibrium than in the inefficient equilibrium (and inversely for the abatement a_0 of the developed country), as the developing country internalizes the marginal abatement benefit of the developed country in the Pareto optimal equilibrium thanks to the operational transfer. Figures 1d and 1e display the utility levels (U_0 and U_1) of the developed country and the developing country respectively. In the inefficient equilibrium, the utility U_0 of the developed country decreases with altruism as its contribution a_0 increases (and inversely the utility U_1 of the developing country increases with altruism). In the Pareto optimal equilibrium, the utility U_0 of the developed country also decreases with altruism because of the transfer increase in this case (and inversely the utility U_1 of the developing country increases with altruism). Moreover, $\hat{\lambda}$, which is located between $\underline{\lambda}$ and $\bar{\lambda}$, characterizes the degree of altruism at which the utility U_1 of the developing country is identical in the two equilibria. The developing country prefers the inefficient equilibrium below $\hat{\lambda}$ and the Pareto optimal equilibrium above $\hat{\lambda}$. Thanks to significant efficiency gain, the developed country prefers the Pareto optimal equilibrium all over $[\underline{\lambda}, \bar{\lambda}]$, which illustrates the idea that the developed country can gain from exhibiting altruistic preferences.

6 Conclusion

This short paper aims at delivering two messages. First, development and environmental policies should be thought together rather than separately. Our result emphasizes that transfers related to development policies can serve as a coordination device, avoiding suboptimalities arising in non-cooperative provision of environmental goods. This involves using an appropriate decision process, where transfers are decided in a second stage, as a function of aggregate abatements. The coordination mechanism, however, only works if the developed country is altruistic (or wealthy) enough so that positive transfers actually flow from the developed country to developing countries.

The second point is that even if the developed country is selfish, the efficiency gains arising when implementing altruistic policies may be larger than the "cost" of helping developing countries. Development policies appear to be then more than a transfer of wealth from developed to developing countries that reduces inequality, but also a way to face global environmental challenges, and in particular those related to climate change.

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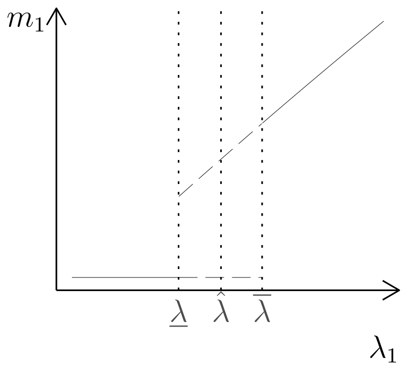
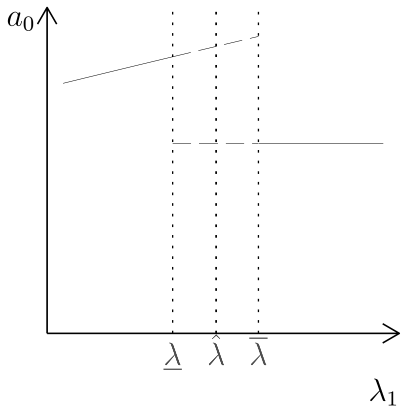
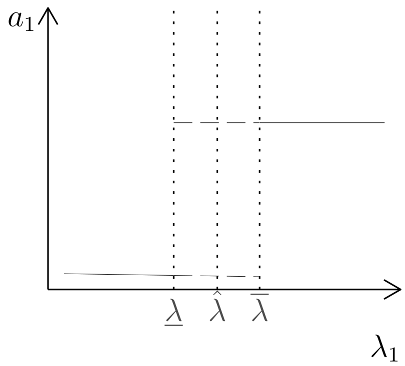


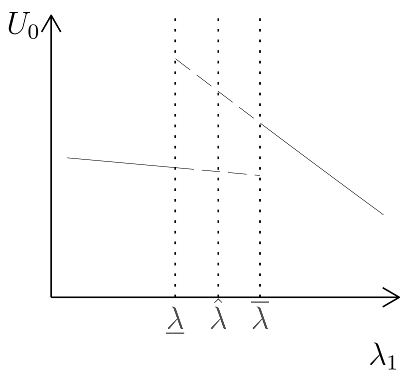
(a) Transfer m_1 w.r.t. altruism λ_1



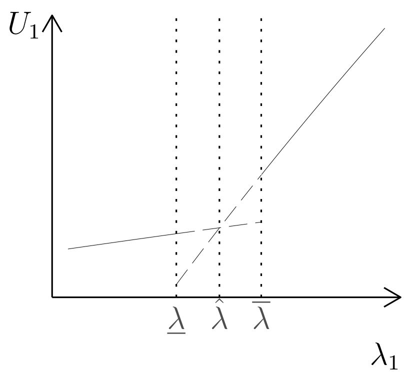
(b) Developed country abatement a_0 w.r.t. altruism λ_1



(c) Developing country abatement a_1 w.r.t. altruism λ_1



(d) Developed country utility U_0 w.r.t. altruism λ_1



(e) Developing country utility U_1 w.r.t. altruism λ_1

Figure 1: The impact of altruism in the sequential game with one developed country and one developing country ($n = 1$).

A Appendixes

A.1 Proof of Proposition 1

A feasible allocation is Pareto optimal if there exists γ_i for all $i \in [1, .., n]$ such that:

$$\begin{aligned}
&\max_{\boldsymbol{m},\boldsymbol{a}} u_0\Big(w_0 - c_0(a_0) + b_0(A) - \sum_{k=1}^{n} m_k\Big) + \sum_{j=1}^{n} \gamma_j u_j\Big(w_j - c_j(a_j) + b_j(A) + m_j\Big) \\
&\qquad \text{s.t.} \quad A = \sum_{k=0}^{n} a_k; \qquad w_0 - c_0(a_0) + b_0(A) - \sum_{k=1}^{n} m_k \geq 0; \\
&\qquad w_i - c_i(a_i) + b_i(A) + m_i \geq 0 \quad \text{and} \quad \gamma_i > \lambda_i, \quad \forall i \in [1, .., n].
\end{aligned} \tag{8}$$

The first order condition of (8) relative to m_i implies:

$$u_0'\Big(w_0 - c_0(a_0) + b_0(A) - \sum_{j=1}^{n} m_j\Big) \geq \lambda_i u_i'\Big(w_i - c_i(a_i) + b_i(A) + m_i\Big). \tag{9}$$

The first order conditions of (8) relative to a_0 and a_i ($i \in [1, .., N]$) are respectively:

$$\sum_{j=0}^{N} b_j'(A) = c_0'(a_0), \tag{10}$$

$$\sum_{j=0}^{N} b_j'(A) = c_i'(a_i). \tag{11}$$

We denote $\boldsymbol{a}^{opt}$ the Pareto optimal allocation which is the solution of (10) and (11). Note that abatement $\boldsymbol{a}^{opt}$ is the same for all the Pareto optimal allocations.

A.2 Proof of Proposition 2

The first order condition of (3) relative to m_i tells that $m_i = 0$ if:

$$\lambda_i u_i'\Big(w_i - c_i(a_i) + b_i(A)\Big) < u_0'\Big(w_0 - c_0(a_0) + b_0(A) - \sum_{\substack{k=1 \\ k \neq i}}^{n} m_k\Big). \tag{12}$$

Otherwise, $m_i \geq 0$ is such that:

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

The first order condition of (3) relative to a_0 and the first order condition of (4) relative to a_i are respectively:

$$\sum_{j=1}^{n} \lambda_j \frac{u_j'(.)}{u_0'(.)} b_j'(A) + b_0'(A) = c_0'(a_0), \tag{14}$$

$$b_i'(A) = c_i'(a_i). \tag{15}$$

We show that $\sum_{i=0}^{n} a_i^{sim} < \sum_{i=0}^{n} a_i^{opt}$ by contradiction. We assume that $\sum_{i=0}^{n} a_i^{sim} > \sum_{i=0}^{n} a_i^{opt}$. Then, (10) and (14) imply $a_0^{sim} \leq a_0^{opt}$ (given that $\lambda_j u_j'(.) \leq u_0'(.)$ in (14)). Moreover, (11) and (15) imply $a_i^{sim} < a_i^{opt}$. Thus, $\sum_{i=0}^{n} a_i^{sim} < \sum_{i=0}^{n} a_i^{opt}$, which contradicts our hypothesis.

We now assume that none of the m_i are strictly binding in zero, which means that $\lambda_j u_j'(.) = u_0'(.)$ in (14). Given that $\sum_{i=0}^{n} a_i^{sim} < \sum_{i=0}^{n} a_i^{opt}$, (10) and (14) imply $a_0^{sim} > a_0^{opt}$.

A.3 Proof of Proposition 3

We show that the allocation in the sequential game is Pareto optimal, if no transfer is binding in zero.

The first order condition of (5) relative to m_i tells that $m_i = 0$ if:

$$\lambda_i u_i'\Big(w_i - c_i(a_i) + b_i(A)\Big) < u_0'\Big(w_0 - c_0(a_0) + b_0(A) - \sum_{\substack{k=1 \\ k \neq i}}^{n} m_k\Big). \tag{16}$$

Otherwise, $m_i \geq 0$ is such that:

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

Thus, (17) defines indirectly $m_i^{seq}(\boldsymbol{a}) \geq 0$, otherwise $m_i^{seq}(\boldsymbol{a}) = 0$.

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

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

$$b_i'(A) + \frac{dm_i^{seq}}{da_i} = c_i'(a_i). \tag{19}$$

The comparative statics of (17) relative to a_j gives:

$$\lambda_i u_i''(.)\Big[-\delta_{ij}c_i'(a_i)+b_i'(A)+\frac{dm_i^{seq}}{da_j}\Big]=u_0''(.)\Big[b_0'(A)-\sum_{k=1}^{n}\frac{dm_k^{seq}}{da_j}\Big] \tag{20}$$

in which $\delta_{ij}=1$ if $i=j$ and $\delta_{ij}=0$ otherwise. Equation (19) tells with (20) by taking $i=j$ that for any $j\in[1,..,n]$:

$$b_0'(A)-\sum_{k=1}^{N}\frac{dm_k^{seq}}{da_j}=0. \tag{21}$$

Equation (21) then tells with (20) that $b_i'(A)+\frac{dm_i^{seq}}{da_j}=0$ for any $i\neq j$, which gives by summing:

$$\sum_{\substack{k=1\\k\neq j}}^{n}b_k'(A)+\sum_{\substack{k=1\\k\neq j}}^{n}\frac{dm_k^{seq}}{da_j}=0. \tag{22}$$

The sum of (21) and (22) gives $\frac{dm_j^{seq}}{da_j}=\sum_{\substack{k=1\\k\neq j}}^{n}b_k'(A)+b_0'(A)$, which gives with (19):

$$b_i'(A)+\sum_{\substack{k=1\\k\neq i}}^{n}b_k'(A)+b_0'(A)=c_i'(a_i). \tag{23}$$

Equations (17), (18) and (23) imply that the allocation in this game is Pareto optimal if no m_i is binding in 0.

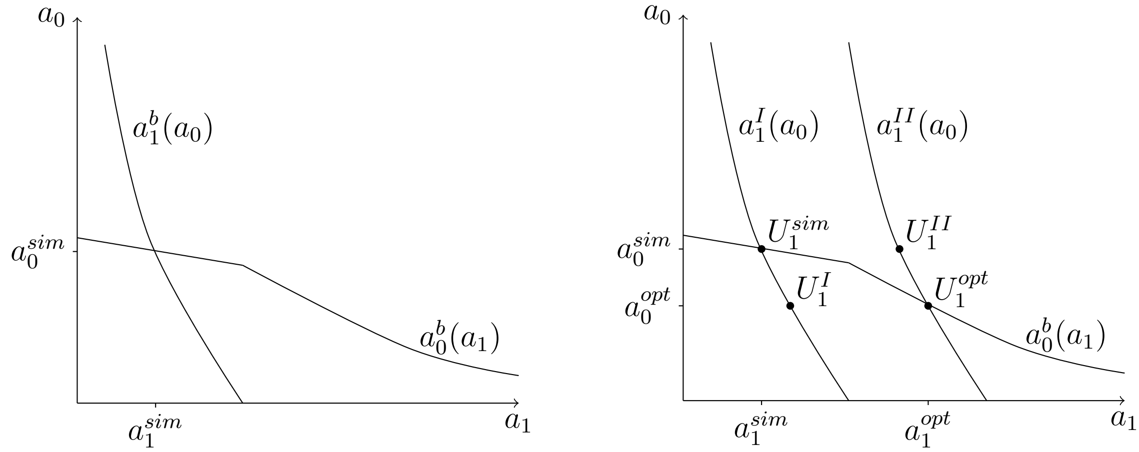
A.4 Proof of Proposition 4

With only one developing country, the first order condition of (3) relative to m_1 tells that $m_1=0$ if $\lambda_1 u_1'(.)<u_0'(.)$. Otherwise, $m_1\geq 0$ is such that $\lambda_1 u_1'(.)=u_0'(.)$. Moreover, the first order condition of (3) relative to a_0 and the first order condition of (4) relative to a_1 are respectively:

$$\lambda_1 u_1'(.)b_1'(A)=u_0'(.)\big(c_0'(a_0)-b_0'(A)\big), \tag{24}$$

$$b_1'(A)=c_1'(a_1). \tag{25}$$

which determine best response functions $a_0^b(a_1)$ and $a_1^b(a_0)$ respectively (represented in figure 2(a)). We show below that the slope of the function $a_0^b(a_1)$ is larger than -1 and the slope of the inverse function of $a_1^b(a_0)$ is lower than -1. So they cross



(a) Simultaneous choice model

(b) Sequential choice model

Figure 2: Abatement best response functions in the simultaneous and sequential choice models with one developing country

once at most. Moreover, by looking at extreme values ($a_0 = 0$ and $a_0 = \infty$), we see that they necessarily cross. In summary, $a_1^b(a_0)$ and $a_0^b(a_1)$ cross once and only once in (a_1^{sim}, a_0^{sim}), and there is a single Nash equilibrium.

To complete the proof, let us analyze the slopes of best response functions $a_0^b(a_1)$ and $a_1^b(a_0)$. The derivation of (24) relative to a_1 states how $a_0^b(a_1)$ evolves with a_1:

$$\frac{da_0^b}{da_1} = \frac{-1+\beta}{1+\alpha} \tag{26}$$

in which we have: $\alpha = -\frac{c_0''}{b_1''+b_0''} > 0$ and $\beta = 0$ when m_1 is not binding in 0, and $\alpha = -\frac{u_0'.c_0''-\lambda_1 u_1''.b_1'^2-u_0''.(c_0'-b_0')^2}{\lambda_1 u_1'.b_1''+u_0'.b_0''} > 0$ and $\beta = \frac{u_0''.b_0'.(c_0'-b_0')}{\lambda_1 u_1'.b_1''+u_0'.b_0''} > 0$ when m_1 is binding in 0. Thus, the slope of $a_0^b(a_1)$ is larger than -1. Note that $a_0^b(a_1)$ goes from $(a_1, a_0) = (0, a_0^b(0))$ to $(a_1, a_0) = (\infty, 0)$. The derivation of (25) relative to a_0 states how $a_1^b(a_0)$ evolves with a_0:

$$\frac{da_1^b}{da_0} = \frac{-1}{1-\frac{c_1''}{b_1''}} \tag{27}$$

Thus, the slope of $a_1^b(a_0)$ is between -1 and 0, and the slope of the inverse function of $a_1^b(a_0)$ is lower than -1. Note that the inverse function of $a_1^b(a_0)$ goes from $(a_1, a_0) = (0, \infty)$ to $(a_1, a_0) = (a_1^b(0), 0)$.

A.5 Proof of Proposition 5

With only one developing country, the first order condition of (5) relative to m_1 tells that $m_1 = 0$ if $\lambda_1 u_1'(.) < u_0'(.)$. Otherwise, $m_1 \geq 0$ is such that:

$$\lambda_1 u_1'\Big(w_1 - c_1(a_1) + b_1(A) + m_1\Big) = u_0'\Big(w_0 - c_0(a_0) + b_0(A) - m_1\Big). \tag{28}$$

Thus, (28) defines indirectly $m_1^{seq}(a_0, a_1) \geq 0$, otherwise $m_1^{seq}(a_0, a_1) = 0$. Moreover, the first order condition of (6) relative to a_0 and the first order condition of (7) relative to a_1 are respectively:

$$\lambda_1 u_1'(.) b_1'(A) = u_0'(.)\big(c_0'(a_0) - b_0'(A)\big), \tag{29}$$

$$b_1'(A) + \frac{dm_1^{seq}}{da_1} = c_1'(a_1), \tag{30}$$

where $\frac{dm_1^{seq}}{da_1} = 0$ if m_1^{seq} is binding in 0 and $\frac{dm_1^{seq}}{da_1} = b_0'(A)$ if m_1^{seq} is not binding in 0. (29) and (30) determine best response functions $a_0^b(a_1)$ (continuous) and $a_1^b(a_0)$ (discontinuous) respectively. In figure 2(b), we represent $a_0^b(a_1)$ and two curves $a_1^I(a_0)$ and $a_1^{II}(a_0)$ representing $b_1'(A) = c_1'(a_1)$ and $b_1'(A) + b_0'(A) = c_1'(a_1)$ respectively. Note that $a_1^I(a_0) < a_1^{II}(a_0)$. Note also that the best response 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. Similarly to appendix A.4, we can show that $a_0^b(a_1)$ crosses once and only once $a_1^I(a_0)$ and $a_1^{II}(a_0)$, which is in (a_1^{sim}, a_0^{sim}) and (a_1^{opt}, a_0^{opt}) respectively.

Are (a_1^{sim}, a_0^{sim}) and (a_1^{opt}, a_0^{opt}) Nash equilibria? In what follows, as represented in figure 2(b), we denote U_1^{sim}, U_1^{II}, U_1^{opt} and U_1^I the utility levels reached by country 1 for abatement (a_1^{sim}, a_0^{sim}), $(a_1^{II}(a_0^{sim}), a_0^{sim})$, (a_1^{opt}, a_0^{opt}) and $(a_1^I(a_0^{opt}), a_0^{opt})$ respectively. We also denote W_1^{sim}, W_1^{II}, W_1^{opt} and W_1^I the corresponding wealth levels reached by country 1. Abatement (a_1^{sim}, a_0^{sim}) is a Nash equilibrium if $U_1^{sim} \geq U_1^{II}$, and abatement (a_1^{opt}, a_0^{opt}) is a Nash equilibrium if $U_1^{opt} \geq U_1^I$. Let us analyze when this is the case.

The aggregate wealth is larger in the Pareto optimal allocation (a_0^{opt}, a_1^{opt}) then in $(a_1^{II}(a_0^{sim}), a_0^{sim})$. Moreover, in these two allocations, weighted marginal utilities are equalized across countries as m_1 is not binding in 0. This implies that $U_1^{II} < U_1^{opt}$.

With $\frac{R_{u_0'} . R_{b_0}}{R_{b_1'}} . \frac{b_0}{w_0 - c_0 + b_0} < 1$ (where $R_f = |\frac{x.f'(x)}{f(x)}|$ by definition), we have β (defined in appendix A.4) smaller than 1 and the function $a_0^b(a_1)$ decreases with a_1 for sure. In this case, we have $a_1^{sim} < a_1^{opt}$ and $a_0^{sim} > a_0^{opt}$ for sure. Given that there is no transfer in the context of $a_1^I(a_0)$, $a_0^{opt} < a_0^{sim}$ implies that $U_1^I < U_1^{sim}$.

With additional conditions, we can show as explained further below that W_1^{opt} and W_1^{II} increase with λ_1 at a higher rate than W_1^{sim} and W_1^I. In this case, there exists $\underline{\lambda}$, $\hat{\lambda}$ and $\overline{\lambda}$ such that $\underline{\lambda} < \hat{\lambda} < \overline{\lambda}$ and:

i) For $\lambda_1 < \underline{\lambda}$, $U_1^{opt} < U_1^I$. In this case, $U_1^{opt} < U_1^I$ and $U_1^{II} < U_1^{opt} < U_1^I < U_1^{sim}$ imply that there is one and only one Nash equilibrium, which is (a_1^{sim}, a_0^{sim}).

ii) For $\underline{\lambda} < \lambda_1 < \hat{\lambda}$, $U_1^I < U_1^{opt} < U_1^{sim}$. In this case, $U_1^I < U_1^{opt}$ and $U_1^{II} < U_1^{opt} < U_1^{sim}$ imply that there are two Nash equilibria. Moreover, no equilibrium Pareto dominates the other ($U_1^{opt} < U_1^{sim}$ and $U_0^{opt} > U_0^{sim}$).

iii) For $\hat{\lambda} < \lambda_1 < \overline{\lambda}$, $U_1^{II} < U_1^{sim} < U_1^{opt}$. In this case, $U_1^{II} < U_1^{sim}$ and $U_1^I < U_1^{sim} < U_1^{opt}$ imply that there are two Nash equilibria. Moreover, one equilibrium Pareto dominates the other ($U_1^{opt} > U_1^{sim}$ and $U_0^{opt} > U_0^{sim}$).

iv) For $\overline{\lambda} < \lambda_1$, $U_1^{sim} < U_1^{II}$. In this case, $U_1^{sim} < U_1^{II}$ and $U_1^I < U_1^{sim} < U_1^{II} < U_1^{opt}$ imply that there is one and only one Nash equilibrium, which is (a_1^{opt}, a_0^{opt}).

To complete the proof, let us explain why W_1^{opt} and W_1^{II} increase with λ_1 at a higher rate than W_1^{sim} and W_1^I with some additional conditions. Given that a change of λ_1 does not affect the wealth of country 1 through a_1 by the envelop theorem and that a_0^{opt} does not depend on λ_1, we have:

$$\frac{dW_1^{sim}}{d\lambda_1} = b_1'(A)\frac{da_0^{sim}}{d\lambda_1} \tag{31}$$

$$\frac{dW_1^{II}}{d\lambda_1} = \left(b_1'(A) + \frac{\partial m_1^{seq}}{\partial a_0}\right)\frac{da_0^{sim}}{d\lambda_1} + \frac{\partial m_1^{seq}}{\partial \lambda_1} \tag{32}$$

$$\frac{dW_1^{opt}}{d\lambda_1} = \frac{\partial m_1^{seq}}{\partial \lambda_1} \tag{33}$$

$$\frac{dW_1^I}{d\lambda_1} = 0 \tag{34}$$

Computing $\frac{\partial m_1^{seq}}{\partial \lambda_1}$ with the derivation of (28) relative to λ_1, we get $\frac{\partial m_1^{seq}}{\partial \lambda_1} = \frac{-u_1'}{\lambda_1 u_1'' + u_0''}$. Computing $\frac{da_0^{sim}}{d\lambda_1}$ with derivations of (29) and (30) relative to λ_1 gives $\frac{da_0^{sim}}{d\lambda_1} < \frac{1}{\lambda_1}\frac{b_1'}{c_0''}$. Moreover, $|b_1'| < c_0'$ and $|b_1' + \frac{\partial m_1^{seq}}{\partial a_0}| < c_0'$ in (a_1^{sim}, a_0^{sim}) and $(a_1^{II}(a_0^{sim}), a_0^{sim})$. Thus, to have W_1^{opt} and W_1^{II} increasing with λ_1 at a higher rate than W_1^{sim} and W_1^I, we just need $2\frac{c_0'}{\lambda_1}\frac{b_1'}{c_0''} < \frac{-u_1'}{\lambda_1 u_1'' + u_0''}$, which is the case if $\frac{R_{b_1}}{R_{c_0'}} b_1 < \frac{0.25}{R_{u_1'}}(w_1 - c_1 + b_1 + m_1)$ and $\frac{R_{c_0}}{R_{c_0'}} c_0 < \frac{0.25}{R_{u_0'}}(w_0 - c_0 + b_0 - m_1)$. The two later inequalities are true with b_1 small relative to the wealth of country 1, c_0 small relative to the wealth of country 0 and coefficients $R_f = |\frac{x.f'(x)}{f(x)}|$ reasonable for some functions $f(.)$ of the model.

A.6 Specification of the illustration for Proposition 5

For the numerical exercise, we choose $u_i(.) = log(.)$, $c_i(a_i) = \alpha_i \frac{a_i^{\delta_i}}{\delta_i}$, $b_i(A) = \beta_i A^{\eta_i}$. The developed country is indexed by 0 and the developing country is indexed by 1. The parameters used to simulate the graphs in Figure 1 are detailed in the following table:

Parameters	α_0	α_1	δ_0	δ_1	η_0	η_1	β_0	β_1	w_0	w_1
Value	0.1	0.1	2	2	0.5	0.5	5	5	50	15