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« The REDD Scheme to Curb Deforestation : A Well-designed system of incentives?»

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The REDD scheme to curb deforestation: A well-designed system of incentives?

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Abstract

Bioprospection is, largely, meant to help reducing deforestation and, the other way around, stopping deforestation enhances the prospects of bioprospection. The need for a global agreement to the problem of tropical deforestation has led to the REDD (Reducing Emissions from Deforestation and Degradation) scheme, which proposes that developed countries pay developing countries for CO_2 emissions saved through avoided deforestation and degradation. The remaining issue at stake is to define the rules defining payments to countries reducing their deforestation rate. This article develops a game-theoretic bargaining model, simulating the on-going negotiation process which is currently taking place within the Convention of Climate Change, after the Copenhagen agreement of December 2009. It shows that the conditions under which developing countries are left to bargain over the allocation of the global forest fund may lead to an ineffective system of incentives. Below a given level of contributions from the North, the mechanism fails to curb the deforestation. Beyond this level, it induces perverse effects: the larger the North's contribution, the larger the deforestation rate. Consequently, the mechanism is most effective only at a specific threshold level which, given the unobservability of countries'preferences, can only be found by a repeated "trial and error" implementation process.

1 Introduction

It is demonstrated that carbon emissions from deforestation could represent up to 20% of anthropogenic carbon emissions (IPCC, 2007). It is also argued that climate change mitigation objectives could be achieved with lower opportunity costs by limiting deforestation rates, especially in tropical countries where the concentration of carbon stored by trees and soils is high, rather than by abating industrial and energy emissions in developed countries (Murray and al., 2009). Hence, curbing CO_2 emissions from tropical deforestation has become an important challenge of international negotiations at the United Nations Framework Convention on Climate Change (UNFCCC). In 2007, the 13th conference of parties (COP) of the UNFCCC adopted the "Bali roadmap" which encouraged parties to explore the feasibility of a new North-South financial transfer scheme, called the United Nations program on Reducing Emissions from Deforestation and Degradation (REDD). The underlying logic of this scheme is simple: it proposes that developing countries be paid for carbon emissions saved through avoided deforestation, either by a system of carbon credits, tradable on carbon markets, or by an international fund, financed mostly by contributions from developed countries. Since then, the policy debate of the last three years has essentially focused on the way such transfer scheme should be designed. The most popular option is to compensate developing countries proportionally to the difference between their observed rate of deforestation and a given reference rate, with a per-unit compensation aligned on the market price of carbon. Therefore, one of the key issues of the negotiations is the definition of reference levels since they will both determine the payments received by each country and the size of the total North-South transfer. It has triggered hot debates amongst developing countries themselves and no consensus has been reached so far.

However, despite this uncertainty, the principle of such scheme was officially endorsed by the international community in the Copenhagen Agreement of December 2009 which stated: "we recognize the crucial role of REDD [...] and agree on the need to provide positive incentives to such actions through the immediate establishment of a mechanism [...], to enable the mobilization of financial resources from developed countries" (UNFCCC, 2010). A number of countries, among them USA, France, and the United Kingdom, have tabled US$ 3.5 billion to get the REDD scheme started for the 2010-2012 period and to encourage broader participation by other donor countries. The international community is therefore facing a situation in which international funding is available to pay for avoided deforestation but the issue of compensation rules remains unanswered. Is it sufficient to ensure the success of the REDD scheme? We argue in this paper that the way the REDD scheme is being negotiated and set-up may induce serious design flaws, which are very likely to make it ineffective. The main reason is that the negotiation over reference levels may lead to perverse incentives. An ineffective REDD scheme could also lead to the acceleration of terrestrial biodiversity loss. A better-designed transfer scheme could be envisaged which could also attract other types of contributors such as bioprospection firms. They would then pay to preserve forested prospection areas.

Our present work develops a game theoretic model of the way international negotiations on REDD are unfolding. This model helps to analyze whether the REDD scheme, as it is negotiated today, can really lead to a successful outcome, or whether it might end up with no gain in avoided deforestation, and the absence of any further financial contributions by developed countries. The article is organized as follows. Section 2 provides a short historical perspective on international negotiations on deforestation and summarizes the main contributions of economic theory to the debate. Section 3 describes a simple framework where the North-South dimension of the deforestation negotiation dilemma can be captured. It uses this framework to investigate the logic of the REDD compensation scheme and to simulate the outcomes of current negotiations over the REDD scheme design. We show that the negotiated mechanism can be effective only for a specific level of contributions by developed countries: under this threshold, it has no impact of deforestation. Above this threshold, any additional funding is counter-productive because it increases deforestation! The fourth section concludes on the welfare properties of such mechanism. Overall, the present analysis shows that the REDD scheme should be designed differently if effectiveness is to be garanteed.

2 Conflicts at stake in the REDD negotiation

Developed countries have long been aware of the alarming rate at which deforestation is taking place in tropical countries and of the irreversible losses associated with the destruction of the primary forest. However, although several attempts were made to establish a multilateral convention on forest protection, in the last 25 years, developing countries have been reluctant to make commitments which could jeopardize their rights to exploit their forestry resources without compensations from the rest of the world. The 1992 Rio summit failed to launch an effective forest convention. Since then, the only outcome of international negotiations on forests has been the adoption of non-legally binding principles concerning sustainable forest management and trade of tropical timber[1].

The failure to reach a global agreement has been however partially compensated by other types of initiatives, mainly driven by biodiversity conservation concerns: there are a few examples of bilateral agreements in which a donor country finances the protection of a specific forest area in a host country; the Convention on biological diversity (CBD) has also promoted a protected area policy, financed through the Global Environment Facility[2] (GEF). In both cases, it is a project-based approach, based on the principle of additionality, in which donor countries only pay for incremental costs of protection in a given area of a host country: they are willing to compensate the operational costs of conservation, as well as a proportion of foregone revenues from land uses other than conservation, for the forest protection measures that would not have been undertaken otherwise by host countries. Although it supposedly satisfies the individual participation constraints of tropical forest countries, it has been limited in scope (Deke 2004), due to cumbersome control and administrative procedures and to the insufficient financial resources of the GEF which depend on voluntary contributions of donor countries. The negotiations on climate change also failed to include deforestation in the 1997 Kyoto protocol, mainly because of methodological and implementation issues. However, the urgency of global warming has brought deforestation back to the forefront and the first proposal for a North-South transfer scheme called REDD, paying for avoided deforestation was tabled in March 2005 by the Coalition of Rainforest nations[3] at the 11th COP of the UNFCCC in Montreal.

The main innovation of REDD is to shift away from a logic of cost compensation towards a logic of purchase of CO_2 storage service. Until then, all transfers were input-based payments, financing implementation costs of forest conservation in host countries. The REDD transfers are output-based payments: they are allocated per unit of real reduction of deforestation rate, compared to a reference level or baseline. The ojective is thus to encourage host countries to reduce their deforestation rate below the agreed reference level. Formally, the transfer T received by the host country is calculated as

[1] For more details on Forest principles see http://www.un.org/documents/ga/conf151/aconf15126-3annex3.htm

[2] The Global Environment Facility (GEF) is a global partnership reuniting 178 countries, international institutions, non-governmental organizations and private firms. It helps to finance sustainable development initiatives in the field of global environmental issues. It is also the designated financial mechanism for some multilateral environmental agreements and framework conventions.

[3] See http://www.rainforestcoalition.org/

$T = t(d^b - d)$ where d^b is the deforestation baseline and d is the observed deforestation rate of the host country. The per-unit payment t should reflect the market price of avoided carbon emissions rather than the individual countries' conservation costs. Host countries retain full sovereignty over the way they want to achieve the reduction in deforestation rate.

With the recognition of the role of REDD (renamed then REDD+ to include enhancement of carbon stock: forest regeneration and rehabilitation, and carbon removals) in the Copenhagen Agreement, the 1999 COP-15 has also obtained the promise by developed countries to provide new and additional resources for the mitigation of climate change and adaptation for developing countries. The collective commitment by developed countries is to provide resources approaching US$ 30 billion for the 3-years period 2010 - 2012 as a "fast-start" fund for adaptation and mitigation. The announced goal, owever, is more ambitious: it is to "mobilize jointly USD 100 billion per year by 2020 to address the needs of developing countries"(UNFCCC, 2010), in addition to official development aid which is supposed to amount already to 0.7% of GDP of developed countries. USA, Japan, Australia, France, Norway and the United Kingdom have already agreed on a fast-start contribution of US$ 3.5 billion for the 2010-2012 period, specifically dedicated to REDD[4]. An agreement in principle on the financial contribution provided by donor countries was therefore concluded but it remains to be seen whether a workable agreement can be reached on the way REDD funds should be allocated.

One of the most debated issues is the mode of calculation of the baseline (Tacconi, 2009). The definition of the baseline will influence decision-making in both donor and host countries, through the calculations of the transfers obtained by host countries, the size of total contributions to be made by donor countries and the net gains in terms of avoided CO_2 emissions. If host countries succeed in negotiating high baselines, they will obtain large transfers without providing much effort in terms of avoided deforestation. On the other hand, too low a baseline will deter their participation in the the REDD program (Karsenty and Pirard, 2007).

Negotiating parties and research institutions have submitted different proposals for the methodology of the baseline calculation: the "historical" baseline would reflect past trends of deforestation rates, at the individual level or at the global level, or a mix of both; the "business-as-usual" (BAU) baseline would be calculated on the basis of the deforestation rate that would occur without the implementation of REDD. Whereas the

[4]See http://ictsd.org/i/news/biores/74825/ for more details.

latter method can end up in endless controversies about the methodology to establish predicted scenarios of deforestation, the former approach penalizes countries with low past rates of deforestation and overlooks the "forest transition" phenomenon[5]. This is already revealed by the strategic positions of Brazil and Indonesia, two large deforesting countries defending the adoption of the historical baseline system, as opposed to the positions of Costa Rica and countries of the Congo Basin, with past low deforestation rates, defending a BAU baseline. Despite the numerous proposals put on the negotiation table, no agreement has been reached on the baseline calculation method so far. The first explanation is that countries have diverging views on the criteria that should justify international transfers: whereas some countries argue that transfers should "punish" past bad behavior, even at the expense of efficiency, others want transfer payments that deter threats of increasing emissions in the future by offering greater compensation to countries with greater nuisance capacity. Another more fundamental reason is that the baseline calculation is a key element in the negotiation strategies of host countries, who are aware that they will have to share between them the funds made available by donor countries to limit deforestation. The discussions about the baseline are to some extent comparable to a bargaining game among developing countries for sharing a new resource.

The hurdle in this international negotiation is quite unusual. In the vast theoretical literature on international environmental agreements, few papers focus on the transfer schemes between developed countries wishing to conserve natural resources with global public benefits, and developing countries which have sovereignty over these resources. Developed countries (or donor countries) have to decide on their individual contributions to the multilateral fund, whereas developing countries (host countries) decide on their participation in the scheme and on the relative effort provided by each in the total conservation effort. The division between developed countries and developing countries of the net surplus generated by the cooperation is also at stake. Barrett (1994) focuses on the free-rider problem in the contribution game to a global biodiversity conservation fund by developed countries. He shows that when a self-enforcing full cooperative agreement is attainable, then the net benefits are small compared to the non cooperative outcome.

[5]Advocates of the forest transition phenomenon argue that high rates of deforestation are only transitory and should decline in time. Rudel et al. (2005) assume two paths to explain the forest transition: the economic development path, economic opportunities and non-farm jobs lead to the abandonment of less productive arable land which can revert into forest, and the scarcity path, the decrease in forest cover fosters landowners and forest compagnies to replenish the forest. This should be taken into account in the revision of the baseline to avoid unnecessary monetary compensations.

Neumayer (2001) summarizes this finding by stating that "cooperation is either narrow (instead of wide) or shallow (instead of deep)". However, Barrett's model, like most models on international cooperation, overlooks the potentially strategic behaviour of developing countries in the transfer game. In the current REDD negotiations, developed countries have recognized the importance of deforestation REDD and have already put a figure on the initial amount available for transfer. Developing countries will have space to negotiate over the sharing rules of these new financial resources. It is not unreasonable to assume that the main driver of the negotiation will be to obtain the largest possible share of the fund, and that developed countries won't have much influence in the negotiation process between host countries, except by establishing the credible threat that that they can withdraw from the fund, if they are in disagreement with the outcomes of the negotiation on sharing rules. Rupert et al. (2004) are the only authors who look more specifically at the recipient countries' joint strategies in a North-South game. They use a biodiversity bargaining game in which developing countries act strategically to extract more surplus from donor countries: they show that badly-designed institutions can in fact engender perverse effects which reduce biodiversity conservation instead of stimulating it.

We use a similar approach to build a stylized model of the North-South negotiation over the implementation of the REDD scheme in which the developed countries' decisions are their financial contributions to the global fund and the developing countries' strategic decisions are their individual deforestation rate. The originality of the model is to endogenize the decision on individual baselines by making it the outcome of a South-South negotiation.

3 The North-South bargaining model

Consider two developing countries in the South (labelled $i = 1, 2$) with a high endowment of forests. The North (representing developed countries)can decide to contribute to a global transfer fund which is used to pay rewards to developing countries accepting to reduce their deforestation levels under a given individual baseline. The size e of the global transfer fund set by the North is known by developing countries. Let $d_i \in]0, d_i^{max}[$, $i = 1, 2$, be the area deforested by country i, where d_i^{max} is the total forest area of country i. Let (d_1, d_2) be the vector of deforestation decisions.

Southern countries' preferences are captured by utility functions $U^i(d_i\ , w_i + T_i)$. The two arguments of their utility function is deforestation d_i (which provides land, fuelwood, and timber) and initial exogenous wealth w_i which can be increased by transfers T_i from the North. Note that the global public good role of forests does not appear in utility functions of the South. Indeed, developing countries are concerned by climate change but they consider that efforts to mitigate climate change should be supported by the North only. The global quantity of forests, although it may contribute to curbing global warming, is not considered by developing countries as a global public good [6]. Utility functions U_i are continuous, strictly increasing and concave. They satisfy the following intuitive properties:

$$U_1^i = \frac{\partial U^i}{\partial d_i} \begin{cases} \geq 0 & \forall d_i \in \left]0, \overline{d}_i\right[\, , \\ = 0 & \forall d_i \in \left[\overline{d}_i, d_i^{max}\right[\, , \end{cases} \tag{1}$$

$$U_2^i = \frac{\partial U^i}{\partial \left(w_i + T_i\right)} \geq 0, \tag{2}$$

$$U_{11}^i = \frac{\partial^2 U^i}{\left(\partial d_i\right)^2} \leq 0, \quad U_{22}^i = \frac{\partial^2 U^i}{\left[\partial \left(w_i + T_i\right)\right]^2} \leq 0. \tag{3}$$

Property 1 indicates that beyond a given deforestation threshold $\overline{d}_i$, the marginal utility of additional deforestation is zero because the remaining forested area is unsuitable for the development of farming and logging activities, due to geographical reasons (remoteness from roads and markets), bio-physical reasons (nature of soils, slopes, climatic conditions) or economic reasons (the net profitability of deforestation becomes negative).

In the rest of the paper, and without loss of generality, we will limit the analysis to the case when the marginal utility of deforestation is not changed by the level of wealth:

Assumption 1

$$U_{12} = 0\,. \tag{4}$$

Although such an assumption is not easily testable, we assume that Southern countries eligible for REDD payments have not reached the inversion point of the "forest transition" phase. The utility of deforestation is very high and a change in exogenous wealth has little or no effect on the marginal utility of deforestation.

This simple model captures the logic underlying the North-South deforestation dilemma: Southern countries can enjoy the same or perhaps a higher level of utility after limiting deforestation, provided their sacrifice is offset by a sufficient increase of the second argument, wealth, through financial transfers.

[6] A formulation that captures this role would have d_j, $j \neq i$, as a third argument in the utility functions.

The REDD mechanism compensates developing countries which reduce their deforestation below a baseline level d_i^b, $d_i^b < \overline{d_i}$. The financial transfers T_i are paid proportionnally to the difference between the observed deforestation rate and the baseline:

$$T_i = \begin{cases} t\left(d_i^b - d_i\right) & if \qquad d_i < d_i^b\,, \\ 0 & otherwise. \end{cases}$$

t is the transfer rate. It reflects the value of avoided deforestation in terms of reduced emissions of carbon [7]. The budget of the global transfer fund must balance. Therefore, if the sum of the Northern countries' contributions to the fund is e then:

$$T_1 + T_2 = e\,.$$

Under the *laissez-faire* scenario, in the absence of the REDD mechanism, there are no monetary tranfers ($T_1 = T_2 = e = 0$) and Southern countries settle for deforestation decisions d_i^N:

$$U_1^i\left(d_i, w_i\right) = 0 \qquad \Rightarrow \qquad d_i^N \in \left[\overline{d}_i, d_i^{max}\right[\ .$$

Country i is indifferent between any deforestation decision $d_i^N \in \left[\overline{d}_i, d_i^{max}\right[$: we assume that it will choose to deforest $\bar{d}_i$. The resulting global deforestation level $\overline{d}_1 + \overline{d}_2$ is judged to be too high by Northern countries: they are willing to contribute to a common financial fund e, in order to compensate Southern countries accepting to reduce their deforestation activities.

In the rest of the paper, we will assume usual Inada conditions to avoid corner decisions in the domain $]0, d_i^b]$:

Assumption 2

$$\lim_{d_i \to 0} \left\{U_1^i\left[d_i, w_i + t\left(d_i^b - d_i\right)\right] - tU_2^i\left[d_i, w_i + t\left(d_i^b - d_i\right)\right]\right\} > 0\ .$$

Assumption 3

$$\lim_{d_i \to d_i^b,\ d_i < d_i^b} \left\{U_1^i\left[d_i, w_i + t\left(d_i^b - d_i\right)\right] - tU_2^i\left[d_i, w_i + t\left(d_i^b - d_i\right)\right]\right\} < 0\ .$$

[7]It was suggested in a number of arena that t could be measured as follows: $t = CD * 3.66 * PC$ where CD is the carbon density of preserved forests ($tonC/Ha$), 3.66 is the atomic ratio of carbon dioxyde to carbon ($tonCO_2/C$) and PC is the price of an emission permit for one ton of CO2, on existing carbon markets.

Under Assumptions 2 and 3 and the other assumptions made so far, there exists an interior local maximum d_i^* to the utility function in the interval $\left[0, d_i^b\right]$. It will also be a global maximum when:

Assumption 4 $U^i\left(d_i^*, w_i + t\left(d_i^b - d_i^*\right)\right) \geq U^i\left(\overline{d}_i, w_i\right).$

Under Assumptions 2, 3 and 4, country i's utility, as a function of d_i, is depicted in Figure 1. It has a discontinuity point at $d_i = d_i^b$.

We assume that international negotiations on the implementation of REDD run as follows:

1. The North decides upon the size of the international fund e. This stage corresponds to the collective commitment by Northern countries at the COP-15 to provide USD 30 billion for the period 2010-2012, which will partly finance REDD+ activities. To this fund should be added USD 3.5 billion provided specifically for REDD+ by a subset of developed countries[8].

2. Southern countries bargain amongst themselves over their respective baselines knowing the size of the global transfer fund e and the per unit "price" for avoided deforestation t . Northern countries do not take part directly in this negotiation. They nevertheless retain strong bargaining power since they can decide to withdraw their financial contributions to e if the decisions made by Southern countries do not suit them. Therefore the South, as a whole, is confronted with a take-it-or-leave-it offer.

3. Once the rules upon the baselines are set, Southern countries independently choose their deforestation rates by maximizing their utility. We assume in this formal model that countries can control the deforestation rate. The reality is more complex since deforestation is the outcome of decentralized actions by many private agents who are not easily controlled and monitored by public authorities. However, since the REDD mechanism implicitly assumes that the state can inforce its decisions on deforestation agents, we adopt the same set of assumptions.

The model is solved by backward induction. An example using a logarithmic utility is provided in the first appendix.

[8]USA, Japan, Australia, France, Norway and the UK.

3.1 Deforestation decisions

In the last decision period, developing countries choose their optimal deforestation level d_i^* which maximizes their utility under the REDD mechanism, knowing their baseline d_i^b (determined in the previous period). We focus on the solution d_i^* of the utility maximization when $d_i^* < d_i^b$. Formally, optimal deforestation decisions then solve the first order conditions:

$$U_1^i\left(d_i^*, w_i + T_i\right) - tU_2^i\left(d_i^*, w_i + T_i\right) = \ 0, \ i = 1, 2. \tag{5}$$

From the first order conditions of the utility maximization problem, using the implicit function theorem one can calculate:

$$\frac{dd_i^*}{dd_i^b} = \frac{t^2U_{22}^i - tU_{12}^i}{U_{11}^i - 2tU_{12}^i + t^2U_{22}^i} = \frac{tU_{12}^i - U_{11}^i}{U_{11}^i - 2tU_{12}^i + t^2U_{22}^i} + 1\ . \tag{6}$$

Under Assumption 1, we have:

$$\frac{dd_i^*}{dd_i^b} = \frac{t^2U_{22}^i}{U_{11}^i + t^2U_{22}^i} = \frac{-U_{11}^i}{U_{11}^i + t^2U_{22}^i} + 1\ . \tag{7}$$

Given assumptions 3 , we can infer from Equation (7) that:

$$\frac{dd_i^*}{dd_i^b} \ \in \,]0, 1[\ . \tag{8}$$

This result indicates that country i's deforestation increases, but less than proportionally, with the baseline level d_i^b that is negotiated in the second stage.

Remark 5 *From (5) and using the implicit function theorem:*

$$\frac{dd_i^*}{dt} = \frac{U_2^i + (tU_{22}^i - U_{12}^i)(d_i^b - d_i^*)}{U_{11}^i - 2tU_{12}^i + t^2U_{22}^i}\ .$$

The sign of this expression is surprisingly ambiguous: intuitively, we expect that a higher compensation rate per unit of avoided deforestation t reduces the optimal deforestation decision d_i^*. However, this is only the case if $t \leq \frac{-U_2^i}{U_{22}^i(d_i^b - d_i^*)}$. If $t > \frac{-U_2^i}{U_{22}^i(d_i^b - d_i^*)}$, Southern countries will not need to reduce further their deforestation to receive a higher payment. This shows that the choice of t is crucial in the effectiveness of the scheme.

3.2 Bargaining over the baselines in the South

In the second period, Southern countries anticipate the third period decisions described above and have been informed about the size of the global fund e from Northern countries We assume that Southern countries bargain between themselves on the value of their respective baselines, knowing that they cannot collectively claim more than e and that they have no interest to claim less than e. Whatever the bargaining procedure, they will reach a compromise $\left(d_1^{b*}, d_2^{b*}\right)$ which satisfies the following budget constraint:

$$e = t(d_1^b + d_2^b - d_1^* - d_2^*)\ . \tag{9}$$

Hence, the outcome of the bargaining $\left(d_1^{b*}, d_2^{b*}\right)$ must belong to the following *feasible set*:

$$\Omega = \left\{ \left(d_1^b, d_2^b\right)\ /\ \frac{e}{t} = d_1^b + d_2^b - d_1^* - d_2^*,\quad d_1^b \leq \overline{d}_1,\quad d_2^b \leq \overline{d}_2 \right\}\ . \tag{10}$$

The bargaining over the baseline can be conceptualized in several ways. We use here the Nash bargaining solution concept.

Let's define each country's indirect utility functions as follows:

$$H^i(d_i^b)\ \equiv U^i[d_i(d_i^b), w_i + t\left(d_i^b - d_i(d_i^b)\right)]. \tag{11}$$

If Southern countries fail to reach an agreement, there will be no North-South transfers and Southern countries will choose their maximum deforestation rate $\overline{d}_i$ Indirect utilities will be:

$$\overline{H}^i \equiv U^i\left(\overline{d}_i, w_i\right).$$

Assuming that the bargained outcome is given by the Nash solution$\left(d_1^{b*}, d_2^{b*}\right)$, and that $\left(\overline{H}^1, \overline{H}^2\right)$ represent the utilities at the threat points for country 1 and country 2, then $\left(d_1^{b*}, d_2^{b*}\right)$ must solve:

$$max_{\left(d_1^b, d_2^b\right)\in\Omega} \left[(H^1(d_1^b) - \overline{H}^1\right]^{\epsilon_1} \left[H^2(d_2^b) - \overline{H}^2\right]^{\epsilon_2},$$

where Ω represents the feasible set of baseline decisions given by (10); ϵ_1 and ϵ, are the respective bargaining powers of country 1 and 2; and $\epsilon_1 + \epsilon_2 = 1$. The endogenous baselines $\left(d_1^{b*}, d_2^{b*}\right)$ solve the first-order conditions given by:

$$\epsilon_i(H^i - \bar{H}^i)^{\epsilon_i - 1}(H^j - \bar{H}^j)^{\epsilon_j} H^{i\prime} + \epsilon_j(H^i - \bar{H}^i)^{\epsilon_i}(H^j - \bar{H}^j)^{\epsilon_j - 1} H^{j\prime} \frac{\partial d_j^b}{\partial d_i^b} = 0\,, \tag{12}$$

for $i, j = 1, 2,\ i \neq j$.

3.3 Choice of global transfer e by the North

A necessary condition for the North to accept to contribute to the global fund e is that financial transfers be effective and induce a reduction in total deforestation. Let's therefore evaluate the marginal impact of a greater contribution by the North to the global fund e on optimal deforestation decisions by Southern countries, at the optimal deforestation level d_i^*:

$$\frac{dd_i^*}{de} = \frac{dd_i^*}{dd_i^b} \frac{dd_i^b}{de} . \tag{13}$$

We know already from result (8) that $\frac{dd_i^*}{dd_i^b}$ is positive and strictly inferior to 1.

In appendix 2, we demonstrate that $\frac{dd_i^b}{de} \geq 0$.

Proposition *Starting from a level of transfer that sustains an interior optimum for deforestation decisions, the greater the size of the global transfer fund e, the greater the agreed baselines and the larger the deforestation rates.*

Proof. *See above and appendix 2* ■

Therefore, under the assumptions made so far, an increase in the total contributions from the North to the global fund increases the level of deforestation chosen by developing countries! The mechanism implements a wrong incentive program: instead of reducing deforestation further, it induces developing countries to increase their level of deforestation and still gain positive transfers. This result, striking at first sight, is rather intuitive upon reflection. An increase in the size of the global fund is matched by an increase in negotiated baselines because developing countries interpret it as a greater pie to share. This leaves room for an increase of deforestation, provided it is not too large compared to the increment of the baseline, in order to get a strictly positive transfer T_i. Expression (13) along with (8) shows that this is the case because $0 < \frac{\partial d_i^*}{\partial e} < \frac{\partial d_i^b}{\partial e}$. To put it another way, there is a pernicious effect that stems from the endogenous adjustment of the baselines.

As regards financial contributions to the global transfer fund, the North therefore has incentives to downsize them in order to limit the temptation by developing countries to negotiate higher baselines. From the above proposition, this will reduce the baselines and the optimal deforestation decisions in the South. The utility levels attained in the South at the negotiated baselines will also be reduced. Therefore, there may exist a specific level of contributions e^*, the corresponding baselines $\left(d_1^{b*}, d_2^{b*}\right)$ and deforestation rates

(d_1^*, d_2^*), such that for any lower size of the global transfer fund, developing countries will prefer to give up transfers and will choose their maximal deforestation rates. These specific baselines are those that just meet Condition 4; they equalize the utility level at an interior solution with the utility level at the upper corner (see Figures 2 and 3). They are defined as the solution to:

$$\overline{U}^i = U^i[\bar{d}_i, w_i] = U^i[d_i^*, w_i + t\left(d_i^{b*} - d_i^*\right)], \quad i = 1, 2.$$

With those threshold baselines $\left(d_1^{b*}, d_2^{b*}\right)$ and deforestation rates (d_1^*, d_2^*), the corresponding total monetary transfers e^* from the North are calculated as follows:

$$e^* = t\left[d_1^{b*} - d_1^* + d_2^{b*} - d_2^*\right].$$

What the analysis of the present paper reveals is that the North should not contribute more e^*, since this will increase deforestation and cost more at the same time. Should it provide a smaller transfer fund than e^*, given that deforestation levels in the South would then rocket to their maximum levels? The answer depends on the comparison of the North's utility levels achieved at $e = e^*$ and $e = 0$.

Assume that the North's preferences are captured by a continuous and concave utility function $U^3(d, w_3)$ which is decreasing with global deforestation $d = d_1 + d_2$ and increasing with its wealth w_3. Properties of U^3 are the following: $U_1^3 < 0$ and $U_2^3 > 0$.

To summarize:

Proposition *Under Property 1 and Assumptions 1-4 the transfer offered by the North is*

$$e^{**} = \begin{cases} e^* & \textit{if} \quad U^3(d^*, w_3 - e^*) \geq U^3(\bar{d}, w_3)\ , \\ & \\ 0 & \textit{otherwise.} \end{cases}$$

In practice, identifying the threshold e^* is no simple matter, in particular because it depends on utility parameters which are not readily observable. Differently stated, the mechanism is either ineffective, or it implies a waste of resources, except at e^*.

3.4 Welfare properties of the REDD mechanism

Although the REDD mechanism is primarily designed to reduce deforestation, it is interesting to analyze its properties in terms of global welfare. Since there is no supranational authority to enforce the mechanism, it only relies on voluntary participation. Therefore, when the mechanism is effective, i.e. when $e^{**} = e^*$, the utility levels of both Northern and Southern countries are at least the same as in the *laissez-faire* situation and REDD is Pareto improving.

A more ambitious goal for REDD would be to achieve Pareto optimality, while improving welfare for each country. Pareto optimal deforestation decisions d_1^{PO} and d_2^{PO} and wealth allocations m_1^{PO}, m_2^{PO} and m_3^{PO} , if they exist, maximize a global welfare function such as:

$$\gamma_1 U^1(d_1, m_1) + \gamma_2 U^2(d_2, m_2) + \gamma_3 U^3(d_1 + d_2, m_3), \tag{14}$$

where $(\gamma_1, \gamma_2, \gamma_3) \in \Re_+^3$ are respectively the weights of countries 1, 2 and 3 in the global welfare function, $\gamma_1 + \gamma_2 + \gamma_3 = 1$, and m_i is the financial endowment of country i after the transfer: $m_1 = w_1 + T_1$, $m_2 = w_2 + T_2$ and $m_3 = w_3 - e$.

The first-order conditions of this maximization problem are:

$$\gamma_1 U_1^1(d_1, m_1) + \gamma_3 U_1^3(d_1 + d_2, m_3) = 0\,,$$

$$\gamma_2 U_1^2(d_2, m_2) + \gamma_3 U_1^3(d_1 + d_2, m_3) = 0\,,$$

$$\gamma_1 U_2^1(d_1, m_1) - \gamma_3 U_2^3(d_1 + d_2, m_3) = 0\,,$$

$$\gamma_2 U_2^2(d_2, m_2) - \gamma_3 U_2^3(d_1 + d_2, m_3) = 0\,.$$

This set of four equations imposes that the Pareto-optimal solutions (d_1^{PO}, d_2^{PO}, m_1^{PO}, m_2^{PO} and m_3^{PO}) solve the following conditions:

$$\frac{\gamma_1}{\gamma_2} = \frac{U_1^2}{U_1^1} = \frac{U_2^2}{U_2^1}\,. \tag{15}$$

Recall that non cooperative decisions are given by equation (5):

$$U_1^i\left(d_i, w_i + T_i\right) - tU_2^i\left(d_i, w_i + T_i\right) = \;0,\;\; i = 1, 2.$$

Therefore, comparing (15) and (5) Pareto optimality of the Nash equilibrium requires also that the rate of transfer t solves:

$$t = -\frac{\gamma_3 U_1^3}{\gamma_1 U_2^1} = -\frac{\gamma_3 U_1^3}{\gamma_2 U_2^2}\,.$$

The Pareto optimality of the REDD mechanism is therefore a fragile property, because it imposes that the rate of transfer t be calculated on the basis of countries'preferences and weights in the global welfare function, whereas it is in reality planned to be calculated on the basis of the market price of carbon, which itself depends on the number of emission permits that will be delivered under the post-Kyoto agreement. The probability that the market value of t coincides with its Pareto-optimal value is very small. The scenario under which a perfectly-informed supranational authority would impose such value is even less plausible.

4 Conclusion

This stylised model challenges the generally accepted idea that the REDD program is a step in the right direction to curb deforestation. Whereas most studies focus on specific implementation issues, such as additionality, leakage and links to poverty-alleviation projects (for a review, see Angelsen, 2009), this paper shows that the basic principles of the scheme - a payment in return for avoided deforestation - are very likely to be ill-designed and to lead to inefficient outcomes. This is due to the nature of current international negotiations over the definition of REDD allocation rules: we show that a transfer mechanism in which the size of the global transfer is chosen before rules are defined for the baseline can generate perverse incentives. This stems from the fact that it creates incentives for developing countries to negotiate greater baselines, therefore allowing them to minimize their efforts of avoided deforestation in exchange of positive transfers. The mechanism leads to a waste of money when the sum of contributions by Northern countries is higher than a given threshold (let's call it the effective fund size) and it is unefficient to curb deforestation when it is below this level. This result is independent of the structure of preferences of negotiating parties and of their relative bargaining power. Moreover, even if donor countries were able to identify the effective fund sizes, there is no guarantee that the resulting income redistribution and reduced deforestation would lead to a Pareto-optimum, since it would also impose to choose a specific value for unit transfers, reflecting the structure of countries'preferences.

Two practical recommandations can be drawn from this theoretical model. The first one is that if the negotiation process unfolds as previously discussed, the international community should give itself the means to reach the effective fund size without falling into the trap of overcontribution. Of course, what is easily calculated theoretically in a simplified model is impossible to identify in a real-situation setting because coutries have very little information on each other's preferences. However a trial-and-error process could be adopted in which the level of contributions by donor countries will be progressively raised, up to the point when the resulting negotiated baselines will lead to genuinely additive gains in terms of avoided deforestation. The second recommandation is more radical. It imposes to obtain that a firm agreement be reached on the calculation of baselines before any commitment is made on the size of the global fund. This may avoid the trap of perverse incentives but may lead to a deadlock in the negotiation process. These conclusions are of interest for bioprospection policies. At the moment, and despite recurrent attempts by the Convention on Biological Diversity to make progress on this issue, deforestation is mostly discussed within the Convention on Climate Change arena. The justification of REDD transfers is the financial compensation for avoided deforestation in developing countries. A further natural step is to consider that if REDD is successful, it should also facilitate bioprospection agreements, first by conserving more biodiversity-rich forests, and second by linking -why not?- bioprospection rights to the contributions of northern countries to the REDD global fund. Private firms will want to ensure that their contribution leads to efficient outcomes.

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Figure 1: Utility Function

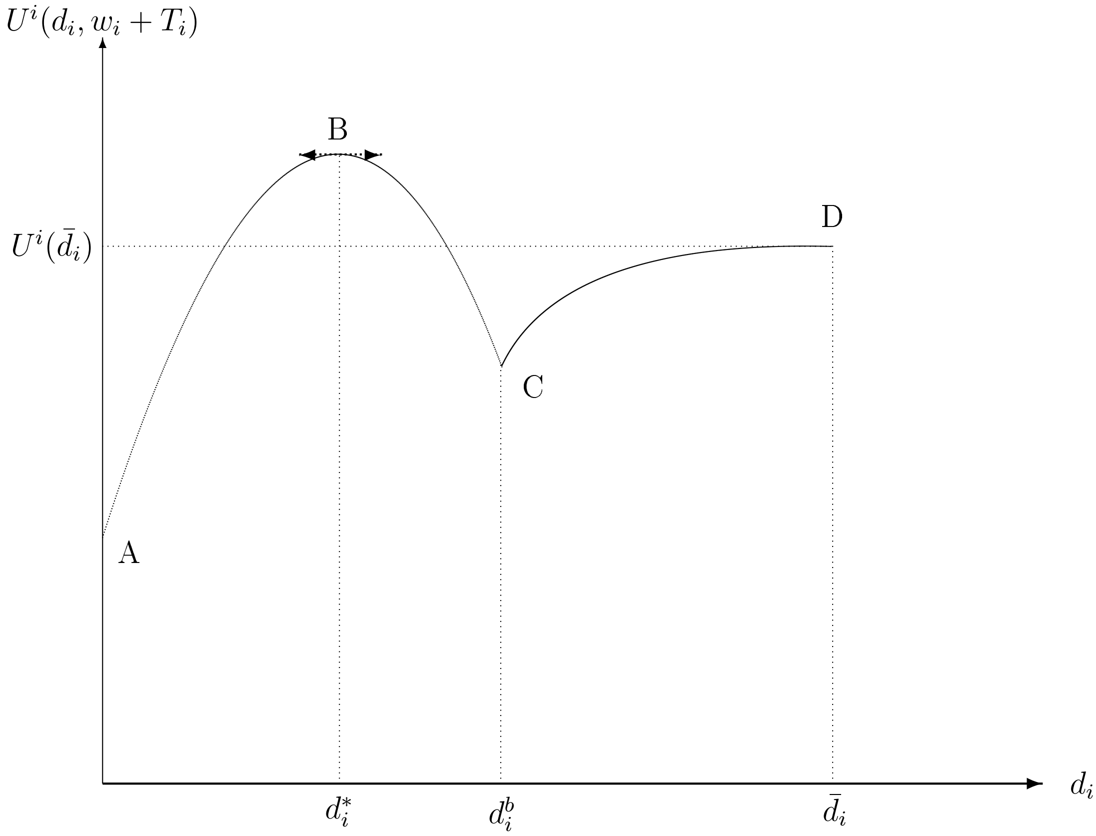
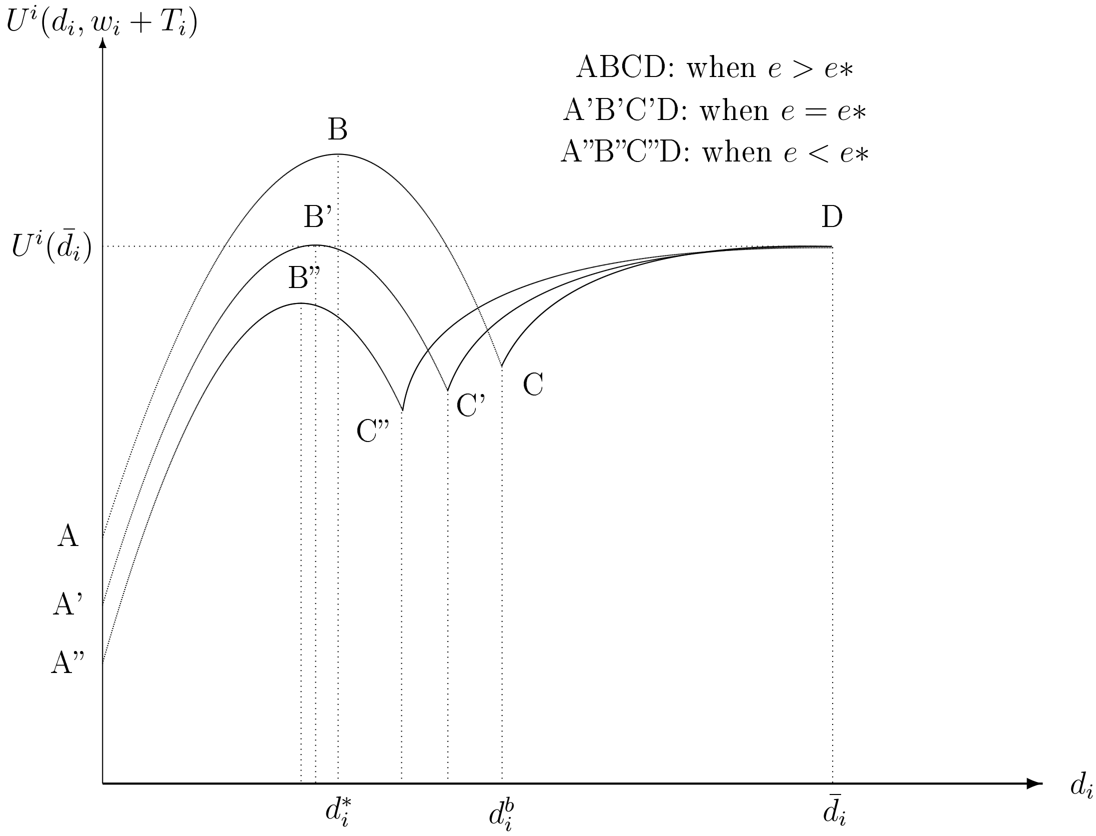


Figure 2: Utility Functions according to e



Appendix 1: A logarithmic example

To illustrate our purpose we could specify utility functionsas follows[9]:

$$U^i(d_i, w_i + T_i) = \alpha_i log(d_i) + \beta_i \ log(w_i + T_i), \quad \alpha_i, \beta_i > 0.$$

Assumption 2, in this log utility example, is automatically satisfied since

$$\lim_{d_i \to 0} \frac{dU^i}{dd_i} = \frac{\alpha_i}{d_i} = +\infty.$$

Assumption 3 imposes $\alpha_i w_i < \beta_i t d_i^b$.

Assumption 4 for a global maximum reads as:

$$\begin{aligned} & \alpha_i \ \log\left(\frac{\alpha_i}{\alpha_i+\beta_i}\frac{w_i}{t} + \frac{\alpha_i}{\alpha_i+\beta_i} d_i^b\right) + \beta_i \ \log\left(\frac{\beta_i}{\alpha_i+\beta_i} w_i + \frac{\alpha_i t}{\alpha_i+\beta_i} d_i^b\right) \\ > \ & \alpha_i \ \log\left(\overline{d}_i\right) + \beta_i \ \log\left(w_i\right) \ . \end{aligned}$$

Assumption 1 is verified since $U_{12} = 0$.

1. Individually optimal deforestation decisions solve:

$$\frac{\partial U^i}{\partial d_i} = 0 \Leftrightarrow \frac{\alpha_i}{d_i^*} \ - \frac{\beta_i t}{w_i + T_i} = 0,$$

$$\Rightarrow \ d_i^* = d_i\left(d_i^b\right) \equiv \frac{\alpha_i}{\alpha_i+\beta_i}\frac{w_i}{t} + \frac{\alpha_i}{\alpha_i+\beta_i} d_i^b.$$

At such an equilibrium:

$$\frac{\partial d_i^*}{\partial t} = -\frac{\alpha_i}{\alpha_i+\beta_i}\frac{w_i}{t^2} < 0,$$

and:

$$0 < \frac{\partial d_i^*}{\partial d_i^b} = \frac{\alpha_i}{\alpha_i+\beta_i} < 1.$$

[9] We could assume for instance that:

$$u_i\left(c_i\right) = c_i \ ,$$

and that consumption is obtained from a production technology such as:

$$c_i = f^i\left(d_i, w_i + T_i\right) = \alpha_i log(d_i) + \beta_i \ log(w_i + T_i), \quad \alpha_i, \beta_i > 0, \quad i = 1, 2.$$

2. In this particular case where utility functions in both tropical countries are the same ($\alpha_1 = \alpha_2 = \alpha$ and $\beta_1 = \beta_2 = \beta$), but $\epsilon_1 \neq \epsilon_2$, $\bar{d}_1 \neq \bar{d}_2$ and $w_1 \neq w_2$, one finds:

$$\frac{dd_i}{de} = \frac{\alpha}{\alpha + \beta} \frac{dd_i^b}{de} > 0\,.$$

Moreover:

$$\begin{aligned} \alpha_i \ \log(\overline{d}_i) + \beta_i \ \log(w_i) &= \alpha_i \ \log\left(\frac{\alpha_i}{\alpha_i + \beta_i}\frac{w_i}{t} + \frac{\alpha_i}{\alpha_i + \beta_i} d_i^{b*}\right) \\ &\quad + \beta_i \ \log\left(\frac{\beta_i}{\alpha_i + \beta_i} w_i + \frac{\alpha_i t}{\alpha_i + \beta_i} d_i^{b*}\right). \end{aligned}$$

If $\alpha = \beta$, we can find the d_1^{b*} and d_2^{b*} that will emerge from the mechanism. To find d_i^{b*} we use the fact that:

$$\log(\overline{d}_i) + \ \log(w_i) = \log\left(\frac{w_i}{2t} + \frac{d_i^{b*}}{2}\right) + \log\left(\frac{w_i}{2} + \frac{t d_i^{b*}}{2}\right).$$

It gives us d_1^* and d_2^* the deforestation levels of countries 1 and 2 when the North contributes e^*:

$$d_i^* = \sqrt{\frac{\alpha_i \bar{d}_i w_i}{\beta_i t}}\ .$$

3. We impose $t < \frac{w_i}{\overline{d}_i}$ to ensure that $d_i^* < \overline{d_i}$, $i = 1, 2$. As for the North's utility function, let us assume it takes the quadratic form:

$$U^3(d, e) = -ad - \frac{b}{2} d^2 - ce - \frac{f}{2} e^2, \quad a, b, c, f \in \Re\,.$$

The welfare function is given by (14). With all those specifications, maximizing the welfare function yields the Pareto optimal levels of deforestation:

$$d_i^{PO} = \frac{\sigma_i \sigma_3 a \alpha_i - \sqrt{\Delta}}{-2b\sigma_3(\sigma_i \alpha_i + \sigma_j \alpha_j)}\,,$$

with:

$$\Delta = (a\alpha_i \sigma_i \sigma_3)^2 + 4b\sigma_3(\sigma_i \alpha_i)^2(\sigma_i \alpha_i + \sigma_j \alpha_j)\ .$$

Paremeters are restricted so that $d_1^{PO} < \overline{d_1}$ and $d_2^{PO} < \overline{d_2}$. If the mechanism is to implement Pareto optimal deforestation decisions, necessarily then:

$$t = t_1^{PO} = t_2^{PO}\,.$$

Appendix 2: Sign of $\frac{dd_1^b}{de}$

Denote $f(d_1^b, e)$ as the function implicitely defined by the first-order condition(12) for $i = 1$ and $j = 2$.

Let ϵ be the bargainig power of country 1 and $(1 - \epsilon)$ that of country 2.

The implicit function theorem states that

$$\frac{dd_1^b}{de} = -\frac{\frac{\partial f}{\partial e}}{\frac{\partial f}{\partial d_1^b}} \quad \text{for} \quad d_1^b = \tilde{d}_1^b\,.$$

To sign $\frac{dd_1^b}{de}$, we need to find the sign of $\frac{\partial f}{\partial d_1^b}$ and of $\frac{\partial f}{\partial e}$:

$$\begin{aligned}
\frac{\partial f}{\partial d_1^b} &= \epsilon[\left(H^{1\prime}\right)^2 (H^2 - \bar{H}^2)^{1-\epsilon}(\epsilon - 1)(H^1 - \bar{H}^1)^{\epsilon-2} \\
&+ H^{1\prime\prime}(H^1 - \bar{H}^1)^{\epsilon-1}(H^2 - \bar{H}^2)^{1-\epsilon} \\
&+ (H^1 - \bar{H}^1)^{\epsilon-1}H^{1\prime}(1-\epsilon)(H^2 - \bar{H}^2)^{-\epsilon}\frac{\partial d_2^b}{\partial d_1^b}H^{2\prime}] \\
&+ (1-\epsilon)[\epsilon(H^1 - \bar{H}^1)^{\epsilon-1}(H^2 - \bar{H}^2)^{-\epsilon}H^{1\prime}H^{2\prime}\frac{\partial d_2^b}{\partial d_1^b} \\
&+ (H^1 - \bar{H}^1)^{\epsilon}(-\epsilon)(H^2 - \bar{H}^2)^{-\epsilon-1}(\frac{\partial d_2^b}{\partial d_1^b}H^{2\prime})^2 \\
&+ (H^1 - \bar{H}^1)^{\epsilon}(H^2 - \bar{H}^2)^{-\epsilon}(\frac{\partial d_2^b}{\partial d_1^b})^2 H^{2\prime\prime}]\,.
\end{aligned} \tag{16}$$

Note that $(H^1 - \bar{H^1})$ and $(H^2 - \bar{H}^2)$ are positive by construction of the Nash bargaining problem.

From equation 9, one has $\frac{\partial d_2^b}{\partial d_1^b} = -1$. From equation 11, we calculate $H^{1\prime}$:

$$H^{1\prime} = \frac{dH^1}{dd_1^b} = \frac{dd_1}{dd_1^b}U_1^i + t(1 - \frac{dd_1}{dd_1^b})U_2^i\,.$$

At the optimal deforestation decision d_i^*, and using the envelop theorem, one has:

$$H^{1\prime}(d_1^b) = tU_2^i\,.$$

Therefore:

$$H^{1\prime} \geq 0\,. \tag{17}$$

We calculate $H^{1\prime\prime}$:

$$H^{1\prime\prime}(d_1^b) = t\ [U_{21}^1 \frac{dd_1}{dd_1^b} + U_{22}t(1 - \frac{dd_1}{dd_1^b})]\,.$$

Under Assumption 1 and with result 8

$$H^{1\prime\prime}(d_1^b) = t^2 U_{22}(1 - \frac{dd_1}{dd_1^b}) \leq 0\,. \tag{18}$$

Therefore, from equation 16 and results 17 and 18, we have:

$$\frac{\partial f}{\partial d_1^b} \leq 0\,.$$

By symmetry, we also have:

$$\frac{\partial f}{\partial d_2^b} \leq 0\,.$$

Moreover:

$$\begin{aligned}
\frac{\partial f}{\partial e} &= \epsilon(H^1 - \bar{H}^1)^{\epsilon-1} H^{1\prime}(1-\epsilon)(H^2 - \bar{H}^2)^{-\epsilon} H^{2\prime}\frac{\partial d_2^b}{\partial e} \\
&+ (H^1 - \bar{H}^1)^{\epsilon}\frac{\partial d_2^b}{\partial d_1^b}(1-\epsilon)[-\epsilon(H^2 - \bar{H}^2)^{-\epsilon-1}(H^{2\prime})^2\frac{\partial d_2^b}{\partial e} \\
&+ H^{2\prime\prime}\frac{\partial d_2^b}{\partial e}(H^2 - \bar{H}^2)^{-\epsilon}]\,.
\end{aligned}$$

Therefore:

$$\frac{\partial f}{\partial e} \geq 0\,.$$

Finally,

$$\frac{dd_1^b}{de} = -\frac{\frac{\partial f}{\partial e}}{\frac{\partial f}{\partial d_1^b}} \geq 0\,.$$

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