Bargaining over a climate deal: is it worse to wait and see?

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Abstract

Assuming that a North-South transfer is the key to climate cooperation, we ask when and how much the North should offer to the South in return for a commitment to reduce deforestation and forest degradation. In light of the risk of irreversible damage over time, we examine a negotiation with a deadline. We assess the conditions for an agreement to be immediate or delayed, and discuss situations likely to result in negotiation failure. Despite the risk of irreversible damage over time, we show that cooperation is likely to be delayed and characterize situations where North and South fail to agree within the deadline. Although Pareto-improving, cooperation may collapse because of inefficiencies related to incomplete information. We show that in negotiations with a deadline, uncertainty about the benefits deriving from cooperation and the irreversibility of the damage that will be caused if cooperation is delayed, are the two key components affecting choice.

KEYWORDS: climate treaty, deforestation, bargaining, transfer, timing, irreversibility, discounting.

Journal of Economic Literature Classification: C72, K32, K42, Q56.

1 Introduction

Deforestation and forest degradation account for nearly 20% of global greenhouse gas emissions, a level that is second only to the energy sector (UN-REDD 2011)[1]. That makes it practically impossible to stabilize global average temperatures within two degrees Celsius without the forest sector that is, without the participation of the so-called G77 South coalition. North-South cooperation is a major issue in climate negotiations and conflicts during and after ratification of the Kyoto protocol have

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[1] These documents are available on the official United Nations website dedicated to the REDD mechanism, see www.un-redd.org.

made clear that problems related to burden sharing are the principal impediment to cooperation. In early 2001, the US senate passed unanimously the Byrd-Hagel resolution according to which *"the United States should not be a signatory to any Protocol that excludes developing countries from legally binding commitments"*.[2] Developing countries for their part, argued that their minor historical contribution to global warming and their right to develop, exempts them from costly efforts. The outcome was the enforcement of a Kyoto protocol *a minima*, that is, a treaty without the principal producers of greenhouse gases.

The REDD (Reducing Emissions from Deforestation and forest Degradation) negotiations that began in Bali in 2007 and that continued during the Copenhagen and Cancun climate summits in 2009-2010, brought the North-South deal back to the negotiating table. REDD provides a mechanism aimed at creating a financial value for the carbon stored in forests, and offers pecuniary incentives to developing countries for reducing emissions from forested lands. North and South have a common interest in achieving cooperation - the North being interested in a low cost carbon policy, the South in being paid in order to provide climate protection. However, the parties interests are not well aligned: the North would prefer a small transfer while South is seeking a significant reward. The UN predicts that the financial flow from REDD+ could reach up to US$30 billion a year (UN-REDD 2011). The design of the mechanism is still not definitive and the question of how much, to where and when to transfer is still being negotiated.[3]

The focus in this paper is *how much* the North should transfer and *when*. We assume that the North can adopt a tough or a soft strategy, and offer a small or a big transfer to the South. A generous offer would ensure immediate cooperation to halt deforestation, while a small offer would introduce the risk of agreement being postponed. For the North, the choice relies on the balance between the

[2] http://www.nationalcenter.org/KyotoSenate.html

[3] This is anecdotal but note that the US$250 millions transfer offer from Norway to Guyana in order to protect the entirety of the latter's remaining forest cover as a giant carbon offset is still frozen after four years of negotiations and one year after the signing of a formal comprehensive agreement. Guyana's President Bharrat Jagdeo complained in Cancun that Guyana had "not seen a single cent expended as yet...".

cost of a transfer policy and the potential irreversible damage that would occur if cooperation is not achieved. This is difficult to assess because the speed of climate change, the associated damage, and the willingness of the South to engage in a binding commitment are uncertain.

To analyse the bargaining process between North and South, we use a repeated offer model. Considering a finite two stage negotiation, we assume that North could propose a high, a median or a low offer in the first period. Cooperation could be achievable with a small amount of aid, but if the offer is too low, South may reject it and any agreement would be postponed to the next negotiation period. We characterize the equilibrium set of the bargaining game and discuss key decision variables in North adopting a *wait and see policy* involving a small amount of aid and observing how South reacts.

The related literature is on international cooperation and the making of international agreements. It examines coalitions likely to emerge at equilibrium, with transfers conceived as a mechanism to ensure coalition stability.[4] There are two approaches within this literature: *the small versus the grand stable coalition* (Tulkens 1998). The latter adopts the analytical framework of endogenous coalition formation (which combines cooperative and non-cooperative concepts) and puts transfer at the heart of the problem. Initially proposed in Chander and Tulkens (1995,1997) the main achievement in this approach is definition of transfer schemes allowing a stable grand coalition to be profitable for all. Although this approach proposes a transfer rule, it does not describe how agreements are reached. This is the principal purpose in the former approach which adopts a non-cooperative game framework to focus on the self-enforceability of agreements. Transfers are analysed as a way to resolve free riding. Carraro and Siniscalco's (1993) seminal paper introduced this idea and making a commitment hypothesis, they show that transfers can enlarge the size of a cooperative coalition. Closely related to the main question addressed in the current paper, Barrett (2001) and Fuentes-Albero and Rubio (2010) ask whether cooperation can be bought. Barrett (2001) considers two

[4] Exhaustive surveys of this literature can be found in Finus (2008) and Jorgensen et al. (2010).

types of countries that differ in terms of their benefits, and proves that cooperation can be bought via a transfer. Fuentes-Albero and Rubio (2010) generalize this result to an asymmetric countries setting that differs in terms of both benefits and costs. Their main conclusion is that transfers increase participation, especially when asymmetries are strong. However, they say nothing about the bargaining procedure involved. To complement these works, we explore the negotiation process. We consider that both North and South have incentives to arrive at an agreement. We assume Pareto improving transfer rules exist and agreement is enforced only if the two coalitions involved in the negotiation agree to be part of it. In other words, rather than focusing on stability, profitability and how transfers affect countries incentives to be part of a treaty, we discuss the bargaining that takes place over that transfer.

Although they do not analyze timing, Rotillon et al. (1996) and Caparros et al. (2004) examine North-South bargaining employing the strategic approach defined in Rubinstein (1982). They model a multi-period game between heterogeneous coalitions with diverging interests. Our approach differs from theirs in three main ways. First, Rotillon et al. (1996) and Caparros et al. (2004) analyse bargaining within an infinite horizon. Coalitions cannot threaten the partner with a negotiation failure in the following stage. However, following failures in negotiations over ratification of the Kyoto protocol at the Conference Of the Parties (COP6) in the Hague in 2000, the Marakesh conference (COP7) in 2001 was held with the threat of a negotiation dead end. Similarly, negotiations in the Cancun summit (COP16, 2010), which followed the failure of the Copenhagen conference (COP15, 2009) to agree on the design of a post-2012 climate treaty, took place in the context of a threat that the framework convention on climate change might collapse.[5] For this reason we include a time constraint - a deadline for negotiations that takes account of the ultimatum effect of a negotiation

[5] Several newspaper articles referred to this threat; for example refer to articles entitle"as threat grows, UN talks face failure" (Sydney Morning Herald, 8 of August 2010), "Why failure of climate summit would herald global catastrophe: 3.5°C" (The Independent, 31 of August 2010) or "Copenhagen climate deal: Spectacular failure - or a few important steps?" published december the 22nd, 2009 in the Guardian.

failure. Second, our approach differs in the utility functions considered. We assume time is costly in the sense that the longer countries wait, the worse the damage will be. The sooner cooperation is achieved, the better it will be for the environment. This illustrates an important property of climate change (Parry et al. 2007) and a fundamental variable in considerations of timing. Third, while the two papers referred above consider offer-counter offer models, we assume that only North makes offers, which South accepts or not. Our model is a repeated offer bargaining model in the sense of Fudenberg and Tirole (1983) and Sobel and Takahashi (1983). We believe this modelling alternative is more appropriate given that in the REDD+ negotiations, South is passive about the amount of the offer and bargains mostly over the design of the mechanism. It would be of little relevance to assume that South would risk negotiation failure by asking for a fixed transfer flow to pay for the opportunity value of its forest. Conversely and in light of the irreversible damage that accumulates over time, North may make a take it or leave it offer if agreement is not reached at a given period of time. Considering this ultimatum effect might be an important dimension of North-South bargaining.[6]

The remainder of the paper is organized as follows. First, we describe the model and the strategy and information structure. Second, we characterize the outcomes and examine the transfer schemes that could emerge from the bargaining process. We study the payoff structure and discuss conditions for the North to adopt *a wait and see policy.* We conclude with a discussion on the main conditions affecting negotiation timing and negotiation failure. To help the readability of this paper, most proofs are relegated to the appendix.

[6]Note that in contrast to a repeated ultimatum game, in our setting the North is far from having full power in this negotiation. The assumption of irreversible damage makes our game one of "a melting ice cake" and finds more analogies with a reverse ultimatum game (Gneezy, Haruvy and Roth, 2003). If South rejects an offer it knows that North's benefit will melt.

2 The model

2.1 Preliminaries

We consider two heterogeneous coalitions[7] denoted by subscript i, with $i = \{N, S\}$, North and South. Each coalition speaks with in a single voice and chooses a level of effort e_i in order to limit a public bad, the environmental degradations caused by climate change. Efforts to limit this public bad is assumed to be substitutable, and we use E to denote the aggregate effort level $E = \sum_i e_i$. This effort benefits each coalition asymmetrically and is individually costly. When the aggregate effort level is E up to period t, coalition i gets $B_i(e_i, t) = D_i(e_i, e_{-i}, t) - C_i(e_i, t)$ where D_i stands for the avoided damage function and C_i is the cost function associated with the individual effort level e_i made over the t periods. Both function is increasing and twice differentiable.

The two coalitions differ. Marginal costs in the South are small compared to the North. Because effort is a public good, both coalitions have an incentive to underprovide it. However, based on reasons of responsibility and ethics, the South free rides while the countries comprising the North coalition have agreed on a common environmental policy, an average effort e_N, for example the Kyoto target. We assume that South is even less concerned about the efforts that its perception of the relative value of damages compared to costs is low. Without transfer South adopts a *business-as-usual* policy e_S, which may well mean no effort. Normalizing, we assume that following a *business-as-usual* policy, $B_S(e_N, e_S, t) = 0$.

Because the marginal cost in the South is small, we consider the bargaining between North and South over the design of a transfer mechanism for the South to make a given level of effort $\overline{e_S} > e_S$. For example, North bargains over a financial flow to the South to avoid deforestation and forest degradation. Maximizing benefits over the two control variables e_i and e_{-i}, North receives an additional benefit which we denote by B, where $B = B_N(e_N^*, \overline{e_S}, 1) - B_N(e_N, e_S, t) > 0$, $B_N(e_N^*, \overline{e_S}, 1)$

[7] Note that we use the term coalition to be consistent with the terminology used in the literature. In this paper, coalitions cannot split and the term refers to a group of countries.

representing the benefit North receives if South agrees to stop deforestation from the first period, $B_N(e_N, e_S, t)$ representing the benefit associated with business as usual over the t periods. For simplicity, we also normalize the *business-as-usual* payoff to zero and we denote the additional benefit B. At the first period, the North is willing to offer a transfer amount $\tau \in [0, B]$ for the South to perform effort $\overline{e_S}$. Although avoiding climate change is desirable for the South, effort $\overline{e_S}$ involves a net cost, $B_S(e_N^*, \overline{e_S}, 1) < 0$. Deforestation and forest degradation is an asset that is even more valuable because North is willing to pay to stop it. We assume that depending on the costs and benefits to preserve the forest but also on the compensation the South expects due to North's responsibility in global warming, South claims for a minimum payment c in order to make effort $\overline{e_S}$, with $c \geq -B_S(e_N^*, \overline{e_S}, 1)$.

The objective of the bargaining is to reach an agreement on the value of the transfer τ that North grants to South to halt deforestation. This agreement translates into a mutually acceptable transfer τ at time t for South to make the effort $\overline{e_S}$. Although North and South benefit from limiting climate change, their interests conflict: North prefers a low τ whereas the South prefers a high one.

Time is an important feature of the problem because in the case of disagreement, negotiations will be postponed to the next period, involving irreversible additional degradation. We consider that this expected degradation α_i increases linearly with time, α_N and α_S are net degradations that accumulate. Because of this degradation, South may either ask for a higher transfer in order to compensate it or accept to join the agreement at a lower price because of the additional damages. We consider the former case in most of the paper and discuss the latter in the concluding section. Time is important also because coalitions discount the future. We consider they discount it uniformly at rate $\delta \in [0, 1]$.

If we focus on the bargaining problem, the objective functions of North and South can be written as:

$$\begin{cases} U_N(\tau,t) = \delta^{t-1}\left[B - \alpha_N(t-1) - \tau_t\right] \\ U_S(\tau,t) = \delta^{t-1}\left[\tau_t - \alpha_S(t-1) - c\right] \end{cases}$$

North's utility is greater the bigger is the net benefit $B - \tau_t$ of an agreement on avoided deforestation, and the faster the agreement is reached. Conversely, South's utility is all the greater that the transfer is high and the opportunity cost of deforestation is low. Like North, South is subject to irreversible degradation in the case that agreement is postponed and prefers immediate cooperation.

2.2 Strategies and information structure

Coalitions know that negotiations take place in a finite sequence of two periods. Although a general model with T periods might be desirable in theory, we reject this feature for two reasons. First, because considering two periods allows for a complete characterization of the equilibrium set. This is not case when considering T periods because more periods involves more equilibria. Multiplicity arises because perfect Bayesian equilibrium imposes no restrictions on players' beliefs following out-of-equilibrium moves. It follows that considering more periods translates into adding restrictions to the model in order to be able to focus on particular equilibria, as in Sobel and Takahashi (1983) and Rubinstein (1985). Second, because climate change negotiation period runs basically over 10 years and a two stage setting is a likely scenario. At the end of the 1990s, countries were bargaining over a climate treaty for the period 2000-2012, they are currently bargaining over the second negotiating period and it is reasonable to assume that if North-South cooperation fails, another agreement will be negotiated within another ten years. In case cooperation fails at that point, it is likely that the current United Nations Framework Convention on Climate Change (UNFCCC) will eventually collapse.

As fort the REDD+ bargaining, we assume that the North deliberates about an amount of transfer to offer to the South to avoid further deforesting. South cannot propose a price to prevent the self-destruction of its forests and can only accept or refuse to comply with the mechanism proposed by the North. However, South can lie about the amount of the net loss $B_S(e_N^*, \overline{e_S}, t)$ it will incur by joining the agreement and we assume that the reservation price of the South c, is imperfectly known by North. This asymmetry is justified by the fact that c reflects some ethical considerations which it is not in South's interests for North to know. South will suffer from the effects of climate change but has other priorities such as developing. Moreover, historically, South is not responsible for the global warming that currently occurs and it claims for compensations. It follows that it is naturally difficult to know South's reservation price. Conversely, because of the large number of studies that document the cost of climate change to the North, we assume that South has complete information on North's cost and benefit functions.

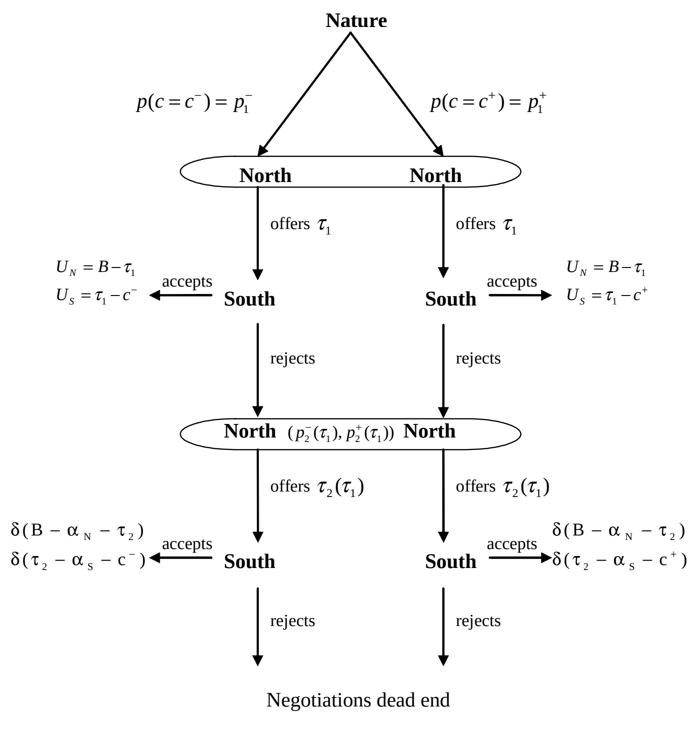

Figure 1. The Game

The game we examine is depicted in Figure 1. In the first period, North which already committed to a climate policy offers a transfer τ_1 to South in return for halting deforestation. South either accepts or rejects the offer; if it accepts, the bargaining ends. The payoffs for the coalitions are then respectively $U_N(\tau_1, 1) = B - \tau_1$ and $U_S(\tau_1, 1) = \tau_1 - c$. If South rejects the offer, the bargaining continues and N makes a new offer τ_2 at the next period. If agreement is achieved at the second period, the payoffs to the coalitions will be $U_N(\tau_2, 2) = \delta(B - \alpha_N - \tau_2)$ and $U_S(\tau_2, 2) = \delta(\tau_2 - \alpha_S - c)$. If bargaining ends in disagreement, both coalitions receive at best a zero payoff. We assume this is the worst possible outcome and it implies by assumption that no coalition has an incentive purposefully to strive for a disagreement.

The South coalition can be of high or low type. If low, South's reservation price is low, and *vice versa*. According to its type, the South coalition is denoted S^- and S^+ and the minimum transfer it will accept is denoted by c^- and c^+, with $c^+ > c^- > 0$. North is not aware of South's type. It does not know the minimum transfer required for South to join the treaty; it knows only a probability distribution which is common knowledge. We write p_t^+ to denote North's subjective probability that South's type is high and p_t^- to denote North's subjective probability that the South's type is low, and $p_t^- = 1 - p_t^+$. In the case that $t = 2$, the probability distribution $[p_2^-(\tau_1), p_2^+(\tau_1)]$[8] is conditional on the fact that, in the first period, North offered a transfer τ_1 which South rejected.

The action set of the North is denoted by X_N and corresponds to the set of feasible transfers from North to South, $X_N \in [0, B - \alpha_N - \alpha_S]$. A pure strategy for N consists of a couple of actions $(\tau_1, \tau_2(.))$ where $\tau_1 \in X_N$ is the transfer offered at the first period and $\tau_2(.) \in X_N$, is the transfer offered at the second period conditional τ_1 being rejected. A mixed strategy for N is a couple of actions $(\mu_1(X_N), \mu_2(X_N))$ where the $\mu's$ are probability distributions over X_N and where μ_2 is conditional on the offer being rejected in the first period of the game. South's action set is $X_S = \{a, r\}$, where a denotes acceptance and r rejection of the offer. A pure strategy for S is a couple of actions

[8] For readibility purpose, in some following equations we abuse notations and write p_2 instead of $p_2(\tau_1)$.

$(s_1(.), s_2(.))$ where $s_1 \in X_S$ is the best reply to the offer τ_1 of N at the first period and $s_2 \in X_S$ is the best reply to the offer τ_2 of N at the second period, conditional on the offer being rejected in the first period. A mixed strategy $(\mu_1(X_S|\, c, \tau_1), \mu_2(X_S|\, c, \tau_1, \tau_2))$ for S is a couple of probability distributions over X_S, conditional on the transfers offered by North and the minimum acceptable transfer level c.

3 Should the North wait and see?

Solving the game with incomplete information requires the use of perfect Bayesian equilibrium. By definition, perfect Bayesian equilibrium requires that both types of South play optimally, that whenever possible, North's beliefs are determined using Bayes' rule, and that North's choices are optimal given these beliefs. Formally, we define it as follows:

Definition 1 *A perfect Bayesian equilibrium of the game is a set of actions* $[\tau_1, \tau_2(.), s_1(.), s_2(.)]$ *and a distribution of conditional probabilities* $\left[(p_2^-(\tau_1), p_2^+(\tau_1))\right]$ *that satisfy properties (1) and (2).*

(1) The strategies $[(\tau_1, \tau_2(.)), (s_1(.), s_2(.))]$ *form a Nash Bayesian equilibrium in each subgame given the probability distribution of North;*

(2) The conditional probabilities $\left[(p_2^-(\tau_1), p_2^+(\tau_1))\right]$ *are consistent with Bayes' rule.*

Note that there is a substantial experimental evidence that casts doubts on the relevance of subgame perfection for analysing several game situations including ultimatum games (e.g. Andreoni and Blanchard 2006). Subjects in ultimatum games exhibit a preference for fairness which may be a critical problem in the context of climate change negotiations. To argue whether perfect Bayesian equilibrium is an appropriate concept in our setting would require a specific experiment on a negotiation that would account for the four features of our model: incomplete information, a deadline, irreversible damages (i.e. melting ice cake) and discounting. Without conducing such an experiment, we can only conjecture, but there is some related experimental findings that supports it. We know from experiments on melting ice cake negotiations that when information is complete and capital depreciation is linear (as in our model), subgame perfection is consistent (Rapoport et al. 1990; Weg and Zwick 1991). We know also from experiments on negotiations with incomplete information on the receiver that perfect Bayesian equilibrium is relevant (Rapoport et al. 1995).[9] One can conjecture that it will be similarly relevant if we run an experiment that combines these two features, which therefore exempts us from including fairness considerations in the utility functions. We believe that this conjecture is all the more reasonable that the game we study is different from a usual ultimatum game setting in that in our model, North pays for a good that South sells which makes strategic aspects more relevant than fairness.

3.1 The one-period game

Because the two-period game is solved by backward induction, we first study the second period game when payoffs are not discounted. Notice first that when information is complete, coalition S^- accepts any offer such that $U_S(\tau_2, 2) \geq 0$, and receives a minimum offer $\tau_2 = c^- + \alpha_S$. Coalition S^+, receives $\tau_2 = c^+ + \alpha_S$. We deduce that in the second period game, pure strategies for North are $c^- + \alpha_S$ and $c^+ + \alpha_S$. As a consequence, we consider $c^- + \alpha_S < c^+ + \alpha_S < B - \alpha_N$, the other cases being trivial. This inequality means that if North makes a high transfer to South, it still achieves a positive benefit. In other words, we focus on situations where there is always an agreement that Pareto-improves the *status quo*.

Let us now study the second period game with incomplete information. North offers a transfer level τ_2 given a probability distribution (p_2^-, p_2^+). South either accepts or rejects the offer and the action $s_2(c, \tau_2)$ relies on South's type and the amount of transfer offered.[10]

When North chooses the pure action $\tau_2 = c^+ + \alpha_S$, the agreement always comes into force and

[9] For an exhaustive discussion refer to Camerer (2003).

[10] In the case of a mixed action, $\mu_2(X_S | c, \tau_2)$, the probability distribution over X_S is conditional on the minimum acceptable transfer level and the amount offered.

North's expected payoff is $p_2^+(B - c^+ - \alpha_N - \alpha_S) + p_2^-(B - c^+ - \alpha_N - \alpha_S) = B - c^+ - \alpha_N - \alpha_S$. When it chooses pure action $\tau_2 = c^- + \alpha_S$, South rejects the offer with probability p_2^+ and the result is that North's expected payoff is $p_2^-(B - c^- - \alpha_N - \alpha_S)$. We deduce that North prefers offer $c^+ + \alpha_S$ to $c^- + \alpha_S$ when $B - c^+ - \alpha_N - \alpha_S > p_2^-(B - c^- - \alpha_N - \alpha_S)$. If we define the bound V such that:

$$V = (1 - p_2^+)c^- + p_2^+(B - \alpha_N - \alpha_S)$$

we can conclude that North offers $c^+ + \alpha_S$ when $c^+ < V$. It offers $c^- + \alpha_S$ when $c^+ > V$ and follows a mixed strategy $(\gamma, 1-\gamma)$ over $\{c^- + \alpha_S, c^+ + \alpha_S\}$ when $c^+ = V$. South always accepts offer $c^+ + \alpha_S$ and it accepts an offer $\tau_2 < c^+ + \alpha_S$ if the reservation price is low.These results are summarized in the following lemma:

Lemma 1 *At the subgame Bayesian equilibrium, North offers:*

$$\tau_2 = \begin{cases} c^+ + \alpha_S \ \text{if } c^+ < V \\ \gamma(c^+ + \alpha_S) + (1-\gamma)(c^- + \alpha_S) \ \text{with } \gamma \in [0,1] \ \text{if } c^+ = V \\ c^- + \alpha_S \ \text{if } c^+ > V \end{cases}$$

and South accepts the offer with probability:

$$\mu_2(s_2 | c, \tau_2) = \begin{cases} 1 \ \text{if } \tau_2 \geq c + \alpha_S \\ 0 \ \text{else} \end{cases}$$

The second period offer relies on the magnitude of the maximum reservation price c^+ relative to three variables: the minimum reservation price c^-, the probability p_2^+ about South's type, and the gains expected from the avoided deforestation if there is an agreement signed at the second period. Note that given $B - \alpha_N - \alpha_S > c^-$, V is always increasing in p_2^+. The more North is pessimistic about South's type, the more likely it will make a higher offer. V is also increasing in the expected gross benefit from deforestation and in the minimum reservation price c^-. We deduce that the higher the expected gains from treaty making and the smaller the reservation price corridor $c^+ - c^-$, the likelier that the offer will be $c^+ + \alpha_S$ because it guarantees an agreement at a low opportunity cost.

3.2 The two-period game

The principal feature of the two-period game is the possibility that North reveals the type of South by making a small offer first. Given the probability that South's type is low, it is questionable whether it would be worth North making a small offer in the first period and, in case of non-agreement, offering more in the second period. We consider the parameters such that $p_1^-(B-c^-)+p_1^+\delta(B-\alpha_N-c^+-\alpha_S) \neq B - c^+$ which is the condition for agreement to possibly be delayed. We study cases where (1) $c^+ < (1-p_1^+)c^- + p_1^+B$ and (2) $c^+ > (1-p_1^+)c^- + p_1^+B$. Considering cost and benefit functions defined earlier, a South's high reservation price means either that the effort $\overline{e_S}$ to comply with an agreement will be high, that South will give a low value to D_S, or that a responsibility/equity bias will lead the South to ask for a significant transfer in order to comply with this effort.

For North and as depicted in the lemma, cases (1) and (2) make the offer conditional to the expected benefits from agreement, the uncertainty about reservation prices and the beliefs about South's type. Rubinstein (1985) would describe this as case (1) depicting a soft North and case (2) a hard North. The main difference is that a soft North never makes a second period offer that could be rejected by the South while a hard North strives for the most favourable deal, even if it postpones the agreement to a next negotiation period.

We first consider case (1) and analyse North's offers. Suppose that there is a perfect Bayesian equilibrium such that a transfer at the first period is $\tau_1 \in [c^-, c^+[$. If τ_1 is rejected by South, then North will update its beliefs according to Bayes' rule:

$$p_2^-(\tau_1) = p\left(c^-, r\middle|\, \tau_1\right)/p(r) = \mu_1\left(r|\, c^-, \tau_1\right)p(c^-)/p(r)$$

where,

$$p(r) = \mu_1\left(r|\, c^-, \tau_1\right)p(c^-) + \mu_1\left(r|\, c^+, \tau_1\right)p(c^+) = \mu_1\left(r|\, c^-, \tau_1\right)p_1^- + \mu_1\left(r|\, c^+, \tau_1\right)p_1^+$$

We deduce,

$$p_2^-(\tau_1) = \frac{\mu_1(r|\, c^-, \tau_1)p_1^-}{\mu_1(r|\, c^-, \tau_1)p_1^- + \mu_1(r|\, c^+, \tau_1)p_1^+}$$

and given $\mu_1(r|\, c^+, \tau_1) = 1$, when $\tau_1 < c^+$ we have,

$$p_2^-(\tau_1) = \frac{\mu_1(r|\, c^-, \tau_1)p_1^-}{\mu_1(r|\, c^-, \tau_1)p_1^- + (1 - p_1^-)} \tag{1}$$

Observe from (1) that $p_2^-(\tau_1) \leq p_1^-$ when $p_1^-(1-p_1^-)(1-\mu_1(r|\, c^-, \tau_1)) \geq 0$ which is always true. By symmetry, we deduce $p_2^+(\tau_1) \geq p_1^+$ and given that the first period offer was rejected, North will update its priors in favour of a high type in the second period. Given that $B - c^-$ is always positive, $p_1^-(B - c^-) \geq p_2^-(\tau_1)(B - c^-)$. By assumption, we have that $c^+ < (1 - p_1^+)c^- + p_1^+ B$ which involves $B - c^+ > p_1^-(B - c^-)$. We can deduce, $B - c^+ > p_1^-(B - c^-) \geq p_2^-(\tau_1)(B - c^-)$ and given α_N, α_S and δ are positive values, we have:

$$\delta(B - c^+ - \alpha_N - \alpha_S) > p_1^- \delta(B - c^- - \alpha_N - \alpha_S) \geq p_2^-(\tau_1)\delta(B - c^- - \alpha_N - \alpha_S) \tag{2}$$

The left hand term of inequality (2) is North's expected discounted payoff when it offers $c^+ + \alpha_S$ in the second period. The right hand term is the expected discounted payoff if it offers $c^- + \alpha_S$ instead. We conclude that for any offer $\tau_1 \in [c^-, c^+[$ rejected by South in the first period, North will always offers $c^+ + \alpha_S$ in the second period.

Consider now the first period offer and define by $\widehat{\tau}$ the lowest transfer level accepted at the first period by a S^- coalition knowing that the lowest transfer offered in the second period is $\tau_2 = c^+ + \alpha_S$. We have $\widehat{\tau} - c^- = \delta(c^+ + \alpha_S - c^- - \alpha_S)$ which means that South accepts the offer $\widehat{\tau}$ in the first period if the expected payoff is the same as the payoff in the second period. We can deduce that $\widehat{\tau} = (1 - \delta)c^- + \delta c^+$ and that South is of a low type if it accepts any offers $\tau_1 \geq \widehat{\tau}$ and is of a high type if it accepts any offers $\tau_1 \geq c^+$. Given that South is fully informed, North is unable to modify South's belief by deviating from its best reply. Likewise, South never deviates from its best reply since inverting its action in the first period will always worsen its payoff.

Let us now examine whether North chooses $\widehat{\tau}$ or c^+ at the first period. Define the mapping $f : \mathbb{R} \to \mathbb{R}$ such that $f = \Pi_H - \Pi_M = B - c^+ - p_1^-(B - \widehat{\tau}) - p_1^+\delta(B - \alpha_N - c^+ - \alpha_S)$ where Π_H and Π_M stand for the payoffs resulting from the high and the median offers at the first period. Notice that $f = 0$ when $c^+ = \overline{c^+} = W + \delta p_1^+ \frac{\alpha_N + \alpha_S}{1-\delta}$ with $W = (1 - p_1^+)c^- + p_1^+ B$. Given f is continuous and strictly decreasing in c^+, $c^+ < W$ and $\delta p_1^+ \frac{\alpha_N+\alpha_S}{1-\delta} \geq 0$, f is always positive which proves that North will always offers c^+ in the first period. We can derive the following proposition:

Proposition 1 *If North is soft, there is a unique perfect Bayesian equilibrium. North offers c^+ in the first period and $c^+ + \alpha_S$ in the second period. Any type of South coalition accepts the first offer immediately.*

Interestingly, this proposition shows that in some situations, the problem of timing might be solved independently of the discount factor and the irreversible damages that would occur in the case that cooperation is postponed. Immediate cooperation is reached thanks to a high North-South transfer as soon as $c^+ < (1 - p_1^+)c^- + p_1^+ B$, that is, in three canonical situations:

- when North's leeway $B - c^+$ for reaching an agreement immediately is high;

- when types c^- and c^+ are close and thus, when uncertainty has a low opportunity cost;

- when North is pessimistic about the type of South, i.e. when p_2^+ is high.

The conjunction of these situations makes it even more likely that condition $c^+ < (1-p_1^+)c^- + p_1^+ B$ will be fulfilled.

Discounting and irreversible damage affect the decision as soon as this condition is not fulfilled. This is the situation depicted in case (2) and in order to categorize decision making we need to define an additional bound that we call $\widetilde{\delta}$, the discount factor value making North indifferent between offering $\widehat{\tau}$ and c^- in the first period. Assuming $\alpha = \alpha_N + \alpha_S$ and $Z = (2p_1^+ - 1)(B - \alpha - c^+) + (1 - p_1^+)(c^- - c^+)$, we have $\widetilde{\delta} = \frac{p_1^+(B-c^-)(B-\alpha-c^+)}{(c^- - c^+)Z}$, a bound that can be written also as $\widetilde{\alpha} = h(p_1^+, B, c^-, c^+, \delta)$ with $\frac{\vartheta h}{\vartheta \delta} < 0$.

In a proof (provided in the appendix), we deduce the following two propositions[11]:

Proposition 2 *If North is hard and if $\delta < \widetilde{\delta}$ (i.e. $\alpha > \widetilde{\alpha}$), there is a unique perfect Bayesian equilibrium: North offers $\tau_1 = \widehat{\tau}$ and $\tau_2 = c^+ + \alpha_S$. South accepts the first period offer if it is of a low type and otherwise accepts the second period offer.*

Proposition 3 *If North is hard and if $\delta > \widetilde{\delta}$ (i.e. $\alpha < \widetilde{\alpha}$), there is a unique perfect Bayesian equilibrium: North offers $\tau_1 = c^-$ and $\tau_2 = c^- + \alpha_S$. South rejects the two offers if it is of a high type and accepts the first period offer with probability $\chi = 1 - \frac{p_1^+(B-\alpha-c^+)}{p_1^-(c^+-c^-)}$ and always accepts the second offer if it is of a low type.*

These propositions tell us that when the leeway $(B-c^+)$ of the North is not sufficiently important, when the corridor of uncertainty $(c^+ - c^-)$ is high or when the North is optimistic that it will be able to buy South's cooperation at a low price, North may take the risk that agreement will be postponed. We deduce that incomplete information introduces inefficiency into the bargaining and makes uncertainty a key factor explaining cooperation delay and negotiation failure. As stated in proposition 3 and despite the fact that agreements are always Pareto-improving, this inefficiency can collapse the negotiations at the two periods ending the process on a disagreement. Cooperation can fail despite the deadline in the case that South's reservation price is high, that North is hard and if over time, there is a small degradation to the benefits from discounting and irreversible damages. This is because given the uncertainty about South's reservation price, North will prefer to sacrifice chances of an agreement with a S^+ coalition in order to benefit a good deal in case South's reservation price is low. As stated in propositions 2 and 3, inefficiency may also delay agreement even if benefits decrease significantly over time (i.e. $\alpha > \widetilde{\alpha}$ and $\delta < \widetilde{\delta}$). In accordance with our intuition, the more

[11] Note that considering simpler utility functions (such that $U_N = B - \tau$ and $U_S = \tau$) and T negotiation periods with $T \to \infty$, Sobel and Takahashi (1983) obtain results that are consistent with our 2-periods model. However, in order to obtain these results, they look at special types of equilibria rather than characterizing the entire set: they examine an equilibrium that is the limit of finite-horizon equilibria.

that benefits depreciate over time[12], the higher will be the first period offer. Finally, note that if North is hard, a high offer will systematically be discarded at the first period because North prefers to take the risk of a negotiation failure in order to minimize the offer.

We finish this interpretation with a sensitivity analysis. Similar to Rubinstein's (1982) complete information model, when South's discount factor decreases (i.e. South becomes impatient) we can expect North's welfare to increases and South's welfare to decrease. We can check that the first assertion is right but not the second. Because it is impatient, probability that South will accept offer $\widehat{\tau}$ at the first period increases. The configuration moves from the equilibrium depicted in proposition 3 to the equilibrium depicted in the proposition 2. It follows that North offers $\widehat{\tau}$ at the first period and $c^+ + \alpha_S$ at the second; the welfare of both coalitions increases in comparison with the equilibrium resulting from offers c^- at the first and $c^- + \alpha_S$ at the second period.

Note that the outcome resulting from offers $(c^-, c^- + \alpha_S)$ is always Pareto dominated by the outcome resulting from offers $(\widehat{\tau}, c^+ + \alpha_S)$. Both coalitions should always prefer the latter offer scheme. However, North knows that if it offers $\widehat{\tau}$ at the first period, South may reject it in order to receive $c^+ + \alpha_S$ at the next period. Incomplete information can involve inefficiency and both coalitions can end up in a worse situation than with complete information.

4 Discussion

What are the insights from this analysis? Recall that our principal aim was to examine strategic bargaining in a North-South climate deal with asymmetric information in order to determine the conditions ensuring agreement. Assuming negotiation with a deadline where the benefits from cooperation decrease over time, we addressed two critical questions : which transfers should North offer to South and when? We studied the conditions for negotiation success, for negotiation delay and for

[12] Irreversible damage is likely to be the principal factor in depreciation, before discounting, the period of time we consider being relatively small.

negotiation failure.

First, we can derive insights into what conditions North's first period offer. If we consider the current bargaining over deforestation, should North offer substantial aid in order that South will halt its deforestation or should it make a low offer and risk a negotiation failure in the first negotiating period? Figure 2 describes our principal findings on this question.

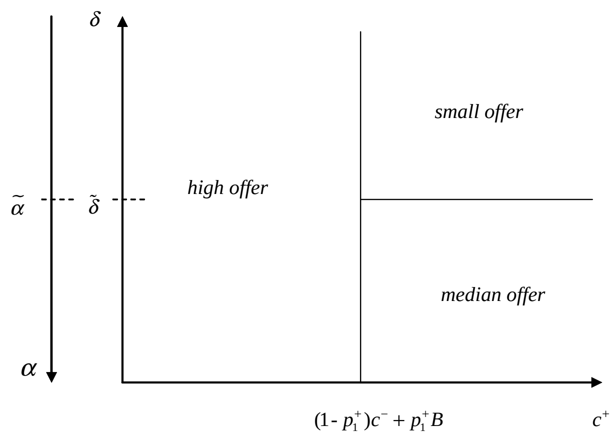

Figure 2. The first-period offer

Due to the irreversible damage that will occur over time and to the fact that coalitions discount future benefits, the intuition would be that North and South should secure cooperation immediately. However, in some situations, North may make a lower offer and risk disagreement in the first period. The reason for trying a low offer is that North does not know the reservation price of the South and this uncertainty leads to inefficiencies that explain a potential agreement delay. An important lesson in relation to decision making and negotiations delay is that over time depreciation of the benefits due to future irreversible damage and to discounting, is second to the benefits that North expects to derive from cooperation and the uncertainty related to it. We observe that when North makes a high offer, this choice is independent of the discount factor and the over time benefit depreciation. A high offer ensures immediate cooperation and North makes this choice because the expected benefit from agreement making is high and the opportunity benefit of risking a negotiation delay is low. This opportunity benefit is related to the probability that South will reject a lower offer, and to the gap between a low and a high reservation price. We can conclude that North makes a high offer because it is not worth taking the risk of postponing cooperation. In the opposite case, where it is worse risking a delay, irreversible damage and discounting become key variables. We confirm that as soon as the depreciation of benefits over time is sufficient, North prefers median to small offers in order to limit the risk of a rejection from South.

Second, we can derive insights into the role of uncertainty and negotiation delays. Because of uncertainty about South's type, North may propose a small or median offer at the first negotiation period, which may be rejected by South. In this case, cooperation is delayed to the next negotiation period. Indeed, we know that with one-sided incomplete information, a low type South is interested in persuading North that its demands are high. Therefore, its strategy consists of adopting high type behaviour. But if discounting and irreversible degradation are not too high, North will have an incentive in the first period to propose a median transfer which is always accepted by a low type South and always rejected by a high type South. We can conclude that delay is a means for North to determine the type of South.

Finally, we can derive insights about Pareto inefficiencies and negotiation failures. An important result from this study is that the two coalitions may fail to agree, despite the fact that agreements are always Pareto improving. This is the case if South is of a high type and expects a high offer and North proposes a small offer in order to ensure a good deal in the case that South will be of a low type.

Note that with the specification of the utility functions considered in the paper, the irreversible damage that will occur over time in the South is always supported by North. This damage might also possibly make South more likely to join the agreement at a lower price in the second period, which would translate into the same model but with adding instead of substracting α_S in the utility function of South. In this case, North does not support the damage in the South but deduces it from its second period offer. If $\alpha_N + \alpha_S$ remains positive all our results are robust. Otherwise, there is a threshold to $\alpha_N + \alpha_S$ such that North will offer $\widehat{\tau}$ at the first period if it is soft, and c^- if it is hard. In other words, North will make lower offers in the first period and South will have an incentive to accept them. In this situation there will still be a positive probability that negotiations will succeed and positive probability that they will fail.

To conclude, and following the suggestion of one of the journal referees, an interesting extension of this work would be to include a third party that would act as mediator and would facilitate negotiations. The question is how this third party could intervene. There are some hints in the literature on this topic about various paths that might be followed (Compte et Jehiel 1995; Manzini et Mariotti 2001; Wilson 2001; Ponsati 2004; Manzini et Ponsati 2006). For Compte and Jehiel (1995), the mediator breaks deadlocks and his intervention relies on the history of the negotiation process, each party being able to ask unilaterally for third party arbitration. For Manzini and Mariotti (2001), arbitration intervenes only after consensus. For Ponsati (2004) and Manzini and Ponsati (2006), the logic is distinct and the mediator offers transfers in order to facilitate negotiations. Finally, in Wilson (2001), the mediator makes random propositions until agreement is reached. The common denominator in all these approaches is that the mediator never imposes his point of view. An interesting line of research is to investigate the objective function of an executive director in negotiations such as those over global warming and to analyse how it affects the game. Acting as a mediator, this executive director might influence the course of the negotiations and we believe this is a topic that requires more analysis given the key role played by former executive directors Jan Pronk, Jean Ripert and Raul Estrada in the making of the Kyoto protocol (Deplege 2005).

Appendix

Proof of propositions 2 and 3 Because they are related, we present a common proof for propositions 2 and 3. This proof proceeds in two steps.

Step 1. We start by characterizing the best response strategies and study the three cases: when $\tau_1 < \widehat{\tau}$, when $\widehat{\tau} \leq \tau_1 < c^+$ and when $\tau_1 = c^+$.

Case 1. If $\tau_1 = c^+$, any type of South accepts the offer in the first period, an agreement is immediately reached and the North obtains $B - c^+$.

Case 2. If $\widehat{\tau} \leq \tau_1 < c^+$, a coalition S^- always accepts the offer in the first period, $\mu_1(a|\, c^-, \tau_1) = 1$, a coalition S^+ always rejects it, $\mu_1(a|\, c^+, \tau_1) = 0$. In case that South rejects the offer in the first period, the North knows with certainty that the South is a coalition S^+ and therefore offers a transfer $c^+ + \alpha_S$ in the second period, which is always accepted. The payoff for North then is $p_1^-(B - \tau_1) + p_1^+\delta(B - \alpha_N - c^+ - \alpha_S)$ and is maximum when $\tau_1 = \widehat{\tau}$.

Case 3. If $c^- \leq \tau_1 < \widehat{\tau}$, coalition S^+ always rejects the offer in the first period, $\mu_1(a|\, c^+, \tau_1) = 0$. Let χ be the value of $\mu_1(a|\, c^-, \tau_1)$ such that the North is indifferent between offering $c^+ + \alpha_S$ and $c^- + \alpha_S$ in the second period when $\mu_1(a|\, c^+, \tau_1) = 0$.

The North updates its beliefs in the second period over the type of S. We have:

$$
\begin{aligned}
p_2^-(\tau_1) &= \frac{[1 - \mu_1(a|\, c^-, \tau_1)]\, p_1^-}{1 - \mu_1(a|\, c^-, \tau_1)} = \frac{(1-\chi)p_1^-}{1 - \chi p_1^-} \\
p_2^+(\tau_1) &= 1 - p_2^-(\tau_1) = \frac{p_1^+}{1 - \chi p_1^-}
\end{aligned}
$$

For North to be indifferent between offers $c^+ + \alpha_S$ and $c^- + \alpha_S$ in the second period, χ should be such that $\frac{(1-\chi)p_1^-}{1-\chi p_1^-}(B - \alpha_N - c^+ - \alpha_S) + \frac{p_1^+}{1-\chi p_1^-}(B - \alpha_N - c^+ - \alpha_S) = \frac{(1-\chi)p_1^-}{1-\chi p_1^-}(B - \alpha_N - c^- - \alpha_S)$ and therefore we have:

$$
\chi = 1 - \frac{p_1^+(B - \alpha_N - c^+ - \alpha_S)}{p_1^-(c^+ - c^-)}
$$

We can prove now that in this case, a S^- coalition always adopts the mixed strategy χ in the first period.

First note that if North offers $\tau_2(\tau_1) = c^+ + \alpha_S$, its expected payoff in the second period is $p_2^-(\tau_1)(B-\alpha_N-c^+-\alpha_S)+p_2^+(\tau_1)(B-\alpha_N-c^+-\alpha_S) = B-\alpha_N-c^+-\alpha_S$. If it offers $\tau_2(\tau_1) = c^-+\alpha_S$, its expected payoff is $p_2^-(\tau_1)(B-\alpha_N-c^--\alpha_S) = (1-p_2^+(\tau_1))(B-\alpha_N-c^--\alpha_S)$.

We can deduce that North adopts $c^+ + \alpha_S$ with probability 1 in the second period only if $B - \alpha_N - c^+ - \alpha_S > p_2^-(\tau_1)(B-\alpha_N-c^--\alpha_S)$ and therefore if $\mu_1\left(a|\, c^-, \tau_1\right) > \chi$. North adopts $c^- + \alpha_S$ with probability 1 in the second period only if $\mu_1\left(a|\, c^-, \tau_1\right) < \chi$ and adopts a mixed strategy which we denote $[1-\sigma_2(\tau_1), \sigma_2(\tau_1)]$ offering $c^+ + \alpha_S$ with probability $\sigma_2(\tau_1)$ if $\mu_1\left(a|\, c^-, \tau_1\right) = \chi$.

Second, note that if North offers $c^+ + \alpha_S$ in the second period, a coalition S^- anticipates it and rejects any first period offer strictly lower than $\widehat{\tau}$. It follows that for $\tau_1 \in [c^-, \widehat{\tau}[\ ,\ \mu_1\left(a|\, c^-, \tau_1\right) = 0$, which contradicts the previous statement. Similarly, if coalition S^- anticipates that North will offer $c^- + \alpha_S$ in the second period, it should accept any offers $\tau_1 \in [c^-, \widehat{\tau}[$ in the first period, which also contradicts the first statement. We can deduce that the only feasible alternative is that a coalition S^- always adopts a mixed strategy χ in the first period which fulfils our claim.

Given that a S^- coalition plays a mixed strategy $\chi \in\ ]0,1[$ in the first period, χ is such that the expected payoff from accepting or rejecting offer τ_1 is the same. We then have: $\tau_1 - c^- = \delta(1-\sigma_2(\tau_1))(c^- + \alpha_S - c^- - \alpha_S) + \delta\sigma_2(\tau_1)(c^+ + \alpha_S - c^- - \alpha_S)$ and, therefore:

$$\sigma_2(\tau_1) = \frac{\tau_1 - c^-}{\delta(c^+ - c^-)}.$$

The expected payoff to North associated with χ is $p_1^-\chi(B-\tau_1)+p_1^-\frac{(1-\chi)p_1^-}{1-\chi p_1^-}\delta(B-\alpha_N-c^--\alpha_S)$ which is maximum when $\tau_1 = c^-$. We can deduce that given that North offers c^- in the first period, it never offers $c^+ + \alpha_S$ in the second period because $\sigma_2(\tau_1) = 0$. The offer in the second period is $\tau_2(\tau_1) = c^- + \alpha_S$. At equilibrium North offers $\tau_1 = c^-$ and $\tau_2 = c^- + \alpha_S$. A coalition S^- accepts the offer with probability χ in the first period and always accepts the offer in the second while a coalition S^+ always rejects the offer. The expected payoff for North is then $p_1^-\chi(B-c^-)+p_1^-\frac{(1-\chi)p_1^-}{1-\chi p_1^-}\delta(B-\alpha_N-c^--\alpha_S)$.

Step 2. We next study the first period offer, that is the conditions for North to offer $c^-, \widehat{\tau}$ or c^+. We can deduce from proposition 1 that North prefers to offer $\widehat{\tau}$ rather than c^+ as soon as $c^+ > \overline{c^+}$. We start by proving that in the case $W < c^+ < \overline{c^+}$, North offers $\widehat{\tau}$ or c^- rather than c^+. Consider the mapping $g : \mathbb{R} \to \mathbb{R}$ with

$$g(\delta) = \Pi_H - \Pi_L = B - c^+ - p_1^- \chi(B - c^-) - p_1^- \frac{(1-\chi)p_1^-}{1 - \chi p_1^-} \delta(B - \alpha_N - c^- - \alpha_S)$$

and where Π_H and Π_L denote respectively North's payoffs when the first period offer is high or low. Note that $g(\delta)$ is decreasing in δ and $g(\delta) = 0$ when $\delta = \overline{\delta} = \frac{(1-\chi p_1^-)[c^+ - \chi p_1^- c^- - (1-\chi p_1^-)B]}{(p_1^-)^2(\chi-1)(B-\alpha_N-c^--\alpha_S)}$. Given $\chi = 1 - \frac{p_1^+(B-\alpha_N-c^+-\alpha_S)}{p_1^-(c^+-c^-)}$, note that $\overline{\delta} \leq 0$ if and only if $c^+ - \chi p_1^- c^- - (1 - \chi p_1^-)B \geq 0$ which is always true. We can deduce that $\overline{\delta}$ is always negative and it follows that for any admissible $\delta \in [0, 1]$, $g(\delta) < 0$ and North always prefers the strategy $(c^-, c^- + \alpha_S)$ to strategy $(c^+, c^+ + \alpha_S)$. North never makes a high offer at the first period.

Next, we show that the choice for North to play either $\widehat{\tau}$ or c^- relies on the degradation of benefits over time. Define the mapping $\Delta : \mathbb{R} \to \mathbb{R}$ with $\Delta = \Pi_M - \Pi_L$ and notice that $\Delta = 0$ when $\delta = \widetilde{\delta} = \frac{p_1^+(B-c^-)(B-\alpha_N-c^+-\alpha_S)}{(c^--c^+)Z}$ with $Z = (2p_1^+ - 1)(B - \alpha_N - c^+ - \alpha_S) + (1 - p_1^+)(c^- - c^+)$ and $\widetilde{\delta} \leq 1$. Define $\varepsilon \in \mathbb{R}$ such that $\delta = \widetilde{\delta} + \varepsilon$ and note that $\Delta = Z\varepsilon$. We next consider the two cases where $p_1^+ \gtrless 1/2$

First, consider the case where $p_1^+ < 1/2$ and note that in this case $\widetilde{\delta} > 0$ because $Z < 0$. We can deduce that Δ is positive when $\varepsilon < 0$ and negative when $\varepsilon > 0$. The median offer is chosen as soon as $\delta < \widetilde{\delta}$.

Second, consider the case where $p_1^+ > 1/2$, *a priori* Z can either be positive or negative. We can prove that given $c^+ > W$. Note that given $p_1^+ > 1/2$, Z is decreasing in c^+ and $Z = 0$ when $c^+ = \widetilde{c} = \frac{(2p_1^+-1)(B-\alpha_N-\alpha_S)+(1-p_1^+)c^-}{p_1^+}$. $\widetilde{c} < W$ as soon as $\alpha_N + \alpha_S > \frac{(1-p_1^+)^2(B-c^-)}{1-2p_1^+}$ which is always true since by assumption, $\alpha_N + \alpha_S \geq 0$ and $p_1^+ > 1/2$. We can deduce that $c^+ > \widetilde{c}$ and therefore $Z < 0$. We conclude that Δ is also positive as soon as $\delta < \widetilde{\delta}$ which completes the proof. ■

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