Cooperation and Reciprocity in Carbon Sequestration Contracts

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Abstract

This paper studies the role of cooperation and reciprocity on the structure of self-enforcing carbon sequestration contracts. The optimal contract is derived as a result of the optimizing actions of purely self-interested agents, and agents that act according to social or egoistic preferences. The analysis finds that buyers' preferences do not affect contract structure unless the buyer is averse to inequality. In contrast, the optimal payment rule is directly related to the seller's preferences as the payment must motivate the seller to comply with forest

conservation. It also finds that the presence of altruistic or warm glow preferences increases the likelihood of cooperation in the long-term relationship relative to the case of selfish parties. These results imply that agencies or organizations that are not only concerned about carbon sequestration but also have objectives related to the economic development of small land holders may be more successful in the implementation contracts to reduce emissions from deforestation and forest degradation.

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Cooperation and Reciprocity in Carbon Sequestration Contracts *

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1 Introduction

The reduction of emissions from deforestation and forest degradation (REDD) presents a key opportunity for mitigating greenhouse gas emissions and maintaining forest cover. However, the success of a REDD strategy regime depends on the design and implementation of a financial mechanism that is effective in providing the right incentives to land-holders to manage forests in a sustainable manner.

Effective REDD contracts must not only properly reward those who reduce deforestation and forest degradation, but also account for technical issues such as permanence and additionality of carbon offsets. Furthermore, contract enforcement becomes complex because the effort and outcomes described in such contracts are difficult to monitor and verify. Therefore, contracts need to provide sufficiently strong incentives to all parties to participate and perform in the long-term, i.e., to be self-enforcing.

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Contracts under which performance (forest conservation) maximizes material payoffs and economic returns for the participants give incentives to parties to choose forest conservation based on material self-interest. However, many economists, including Smith (1759), Becker (1974) and Arrow (1981), have pointed out that people can be concerned for the well-being of others and not only for their own material payoffs. Andreoni (1989), Andreoni (1990) and Videras and Ann L. Owen (2006) posit that people experience a private benefit from contributing to public goods including environmental protection. Moreover, there is large body of experimental evidence that indicates that some people are strongly motivated by fairness and reciprocity concerns as well as by warm-glow giving. Examples of this include Roe and Wu (2009), Fehr and Schmidt (2007), Wu and Roe (2007), Brown et al. (2004), Andreoni and Miller (2002), Andreoni (1990) and Andreoni (1989). The structure of the optimal REDD contracts may vary depending on the degree of altruistic preferences that participants have.

This paper studies three different theoretical models with preferences that go beyond material self-interest to explore the role of cooperation and reciprocity on the structure of self-enforcing carbon sequestration contracts. I examine if the optimal structure of self-enforcing contracts differs if the reciprocity and cooperation are the result of the optimizing actions of purely self interested agents (so called instrumental reciprocity) or if they are the result of the presence of participants who act according to social or egoistic (impure altruistic) preferences.

When parties behave according to purely instrumental reciprocity, i.e. the optimization actions of self-interested agents, the relationship is structured in way where contractual performance (forest conservation) is in each party's personal best interest and agents reciprocate in order to sustain a profitable long-term relationship. This is the baseline assumption in the relational contracting literature and underlies models of self-enforcing contracts such as those by MacLeod and Malcomson (1989), Baker et al. (1994), Baker et al. (2002) and Levin (2003).

If instead, cooperation and reciprocity are the result of agents who act according to social or "warm glow" preferences, the optimal contract may involve a different structure that leverages the non-selfish motivations of individual actors. Models of dynamic contracting relationships in the presence of social and warm glow preferences have been developed and fit via experimental methods by Roe and Wu (2009), Fehr and Schmidt (2007), Brown et al. (2004), Andreoni and Miller (2002), Andreoni (1990) and Andreoni (1989), but have not been derived in general infinite-horizon settings or applied to the carbon sequestration

context as is done in this paper.

To examine how self-enforcing contracts are structured in the presence of agents that derive utility from reasons other than only individual material payoffs, I consider different cases in which one or both parties act according to altruism, spite, inequality aversion or warm-glow concerns and both parties perfectly know each other's preferences.

I find that when the buyer acts according to altruistic reciprocity or spite the structure of the optimal self-enforcing contract is identical to the one in the presence of a self-interested buyer. However, if the buyer is averse to inequality, his payment allocates half of the surplus to the seller. In this case, the total compensation package includes a positive fixed payment and a performance-related bonus that is no greater than the bonus paid when the buyer is self-interested. Therefore, the difference in the total payment is allocated to the fixed payment. These results imply that agencies or organizations that are not only concerned about carbon sequestration but also have objectives related to the economic development of the small land holders should offer the same optimal contract that a profit-maximizing firm offers unless they have preferences about inequality in the allocation of material payoffs.

If the seller is altruistic or experiences a warm-glow from participating in carbon sequestration activities, I find that the optimal contract offers a lower total payment than the one necessary to motivate the seller when she is a purely profit-maximizing agent. There is no fixed payment, and the performance payment includes the value of the cost differential between forest conservation and the value of the alternative use of land less an altruistic or warm-glow value that the seller obtains. That is, the seller is willing to accept a lower payment because she is compensated in her payoffs by an altruistic or warm-glow value derived from participating in the contract. If instead, the seller feels spite towards the buyer, the optimal contract provides a higher total payment than when the seller is purely self-interested. The larger payment has to compensate for the disutility the seller gets from the spite towards the buyer's material payoff. Furthermore, if the seller is averse to inequality, the optimal contracts contain the same payment as when the buyer is averse to inequality.

The degree of self-enforcement of a contract depends on the discount factors of buyer and seller, which I assume to be the same, because the degree to which future returns are discounted determines the incentive to maintain a long-term agreement. I find that the discount factor needed for self-enforcement does not change if parties are fair-minded and averse to inequality when I compare it to the case of self-interested parties. However, I find that the presence of an altruistic reciprocal party (either buyer or seller) increases the likelihood of cooperation in the long-term relationship relative to the case of selfish parties.

The minimum discount factor that sustains cooperation is inversely related to the coefficient of altruism representing one party's sympathy for the other's utility. This result is also true for the case in which either party receives a warm-glow from participating in carbon sequestration activities. The minimum discount factor needed for self-enforcement is also inversely related to the warm-glow coefficient. In practical terms, these results imply that a relationship established for the delivery of carbon offsets between a small land holder and an organization that is concerned about the small land holder's well-being is more likely to deliver cooperation in the long run than a relationship between the same small land holder and an organization that cares only about its own material payoff. The same is true if the small land holder cares about the firm's objectives rather than only being self-interested. Finally, if either party gets additional utility from carbon sequestration per se (warm-glow) then cooperation is also a more likely outcome than if they only receive utility from material payoffs.

In contrast, I find that the presence of a spiteful party decreases the likelihood of cooperation relative to the case of purely profit-maximizing parties. When a party feels spite towards the other party, he gets disutility from any payoffs that the other party gets. As a consequence, the discount factor needs to be higher to compensate for the decrease of utility because of spite so the value of cooperation is greater than the gains from deviation. Then, the range of discount factors that support self-enforcement is smaller. For example, if the buyer of carbon credits is a corrupt government, the seller may feel spite towards the buyer, and therefore cooperation is less likely to occur. By the same token, if the seller is a corrupt government that favors elite groups, the valuation of the future needs to be high enough so that it compensates the buyer as his utility decreases if he trades with this kind of seller.

The remainder of the paper is organized as follows. First, I briefly present the relational contracting model and I characterize the optimal self-enforcing contract in the presence of selfish agents who act according to instrumental reciprocity. Second, I include the possibility that the buyer or the seller act according to altruistic reciprocity or spite. I characterize the optimal contract in these cases and find the parameters under which cooperation is achievable. Third, I consider the presence of inequality-averse parties and I characterize the optimal contract under these circumstances as well as the cooperation parameters. Fourth, I analyze the case in which parties get warm-glow from participating in carbon sequestration activities. Finally, I compare the contract structures and their sustainability with the case of pure instrumental reciprocity and finish with some comments.

2 The Model

Consider the relational contract model in which two purely profit-maximizing risk-neutral parties, a buyer and a seller, have the opportunity to trade carbon emissions offsets at dates $t = 0, 1, 2, 3 \dots$. The seller possesses the exploitation rights for forested land and is interested in adopting land use and management practices that maximize her economic returns. She has the option to conserve the forest and maintain the carbon stocks or she can change the land use to a non-forest activity such as farming and timber harvesting, which would result in carbon emissions.

The buyer is interested in reducing greenhouse gas emissions from the forest clearing. Thus, he is willing to pay the seller to avoid changing the current land use and to maintain the carbon stock captured in the forest for a given period of time. Because carbon stocks only have value if they stay for a sufficient period of time, date t is the period of time that the buyer wants the seller to keep the current land use.

At the beginning of period t , the buyer and the seller agree on an initial baseline of tones of carbon stocked in the forested land exploited by the seller. Once the initial carbon stock baseline is established, the buyer proposes a compensation scheme that the seller receives if she does not change the land use and delivers the quantity of carbon initially agreed, q^* . Compensation consists of a fixed payment p_t and a contingent payment $b_t : Q \rightarrow \mathfrak{R}$, where Q is the observed tones of carbon. Carbon stocks are observable by both parties but they are not enforceable because of weak court systems and weak governance in the developing country. Consequently, the desired carbon, q^* , may differ from the delivered quantity, q_t . We focus here on self-enforcing agreements, without adding the additional layer of analytical complication that would come about from assuming imperfect observability of results. The importance of self-enforcing agreements arises from uncertainty about how actual enforcement mechanisms might work under REDD. If the buyer were a national government (which in turn received payment from an international authority based on certified reductions in deforestation or forest degradation), the seller would have limited remedies if the buyer breached an agreement. There could also be imperfect enforcement against breach by politically powerful sellers who threaten to hold up delivery of certified reductions unless a larger payment is provided. Let $q_t \in Q = [\underline{q}, \bar{q}]$ denote the set of carbon delivered in period t , where $\bar{q}$ represents the tones of carbon dioxide sequestered at the beginning of the period given the initial land use. $\underline{q}$ represents the quantity of carbon sequestered when the land use is completely changed to a profit-maximizing non-forest activity.¹

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¹In this model, I analyze REDD as a tool for limiting deforestation but not for increased afforestation; as

The fixed payment, p_t , is paid independently of the final outcome and it is paid during the course of the trading period t . The contingent payment is considered as a performance payment or *bonus* and it is used to reward compliance with the baseline carbon level and avoidance of deforestation and forest degradation. Since the contingency payment depends on an unenforceable measure, it is not a legally binding obligation.

After observing the compensation scheme, the seller decides whether or not to accept the buyer's offer and her decision set is given by $d_t \in \{0, 1\}$, where 0 denotes rejection and 1 denotes acceptance. If the seller accepts, she receives p , observes the returns of alternative land uses including non-forest activities and decides to adhere to the contract or to change the land use and breach the contract.

If the seller decides to avoid deforestation and forest degradation, she performs under the contract and incurs a cost for forest protection. The cost includes aspects of maintaining the initial state of the forest land such as the seller's opportunity cost of time of taking care of the forest, the cost of materials, e.g. to build a fence around the property, or task difficulty which includes making sure other people do not exploit the forest. The cost is given by $c_t(q_t)$ where $c'(\cdot) > 0$, $c''(\cdot) \geq 0$, and $c(\underline{q}) = 0^2$. The seller's profit is $U_{st}^m = P_t(q_t) - c_t(q_t)$, where $P_t(q_t) = p_t + b_t(q_t)$ is the total payment actually made from the buyer to the seller. At the end of period t and upon delivery, the seller's carbon stock generates a direct benefit for the buyer, $V_t(q_t)$, where $V'(\cdot) > 0$, $V''(\cdot) \leq 0$, and $V(\underline{q}) = 0$. $V_t(q_t)$ represents the buyer's value of the carbon credits generated by the forest conservation. It can be interpreted as the buyer's direct cost of doing his own carbon emission mitigation, and it can also reflect the buyer's value for non-carbon objectives such as biodiversity conservation. The buyer also chooses whether or not to pay $b_t(q_t)$. The buyer's material utility is given by $U_{bt}^m = V_t(q_t) - P_t(q_t)$. Also, $V'(\cdot) > c'(\cdot) \forall q \in Q$, so it is socially efficient and Pareto optimal to maintain the forest land and trade $q = \bar{q}$, since $\bar{q}$ maximizes the total joint surplus defined by $S(q_t) = V(q_t) - c(q_t)$. Note that the superscript m in the objective functions denotes the profit-maximizing preferences which are perfectly known by each party.

If the seller rejects the contract, trade does not occur, the seller receives a fixed payoff from the non-forest activity³ $\bar{u}$ and the buyer receives $\bar{\pi}$ which is equivalent to the alternative

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a consequence, the optimal level of carbon sequestered q^* equals to $\bar{q}$. This assumption can easily be relaxed and impose an exogenous upper bound on how much afforestation might occur, so that q^* cannot be larger than $\bar{q} + \tilde{q}$ where $\tilde{q}$ is the additional carbon sequestered from afforestation. The rest of the analysis goes through for that scenario as well.

²I assume that the fixed costs of harvest and transition are netted out of the returns to the non-forest activity.

³I assume that the net returns of the non-forest activity are always more attractive than sustaining the

source of carbon credits. More generally, the buyer would pay $\bar{\pi}$ for the next cheapest form of compliance (for the same amount of credits) and the value of the contract to the buyer is the cost savings relative to this default option; for example, the buyer can get CDM credits from other projects or alternatively implement a REDD project in another country or with another seller. These options are assumed to be less attractive than trading, but are desirable to the parties if there are insufficient incentives for the parties to trade. The sum of the fixed payoffs, $\bar{s} = \bar{u} + \bar{\pi}$, is the value of the outside opportunities. The net social surplus is given by $S(q_t) - \bar{s}$, where $S(q_t) - \bar{s} \geq 0 \forall q \in (\underline{q}, \bar{q}]$, and $S(\bar{q}) > S(\underline{q}) \geq 0$. The net social surplus is the difference between the return to the relationship and the second-best market opportunity for both parties.

This sequence of events repeats in each period t , and over the course of repeated interactions the parties know only the past actions of the trading partners with whom they have traded allowing for the creation of relationships in which cooperation is an important characteristic. In addition, each party's objective is to maximize the future discounted utility, where the common discount factor is $\delta \in (0, 1]$. The common discount factor captures the time value of money and the probability that the parties will meet again after the current period. If today's interaction is likely to be the last, any dollar to be received in the next period if parties were to interact is not worth as much as if it is received today. Then, the discount factor reflects both time preference and the exogenous uncertainty about the realization of future production opportunities.

Specifically, the objective of a purely self-interested seller is to maximize her present discounted utility, given as

$$(1) \quad \sum_{t=0}^{\infty} \delta^t \{d_t(U_{st}^m) + (1 - d_t)\bar{u}\}$$

and a self-interested buyer's objective is to maximize his present discounted utility

$$(2) \quad \sum_{t=0}^{\infty} \delta^t \{d_t(U_{bt}^m) + (1 - d_t)\bar{\pi}\}$$

where $d_t = 1$ if the seller accepts the contract and trade occurs in period t , and $d_t = 0$ if the seller rejects and no trade occurs.

Because of the weak governance in the developing country, forest conservation is not enforceable by a formal court of law. In this case, parties must rely on informal incentives

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forest without a payments for forest conservation. Then, forest is harvested in the absence of a contract.

and good faith to self-enforce agreements. However, the contingent payments are just a promise, therefore parties have the temptation to deviate from the contract as they do not incur a formal third-party penalty for reneging the original agreement.

If parties were to interact just one time, the buyer can only make the fixed payment credible as it is assumed to be enforceable and paid during the trading period. Because this payment does not include any additional incentives to the seller to continue to sequester the carbon, avoiding carbon emissions from reducing deforestation and forest degradation cannot occur in a static equilibrium. Consequently, trade does not occur and both parties receive their outside options.

In contrast, the ongoing interaction sustains the equilibrium by allowing the parties to support future terms of trade contingent on the satisfactory performance of present trade. This results in a stationary game in which there are only two outcomes of interest: no trade or an infinitely lived contract. If parties do not find incentives to participate in carbon sequestration, there is no trade. But if there is sufficient gains to trade, parties engage in a long-term carbon sequestration relationship. The parties cooperate if the history of play in all periods has been cooperation, where cooperation is defined as both parties fulfilling the contract. The parties break-off trade forever if any deviation is observed. There is no loss in assuming that deviation causes the parties to break-off trade forever because this outcome never happens in equilibrium (Levin, 2003). Furthermore, it can be assumed that after any deviation parties behave as they would in one-time interactions in which the buyer offers a contract in which there is no performance incentives and the seller responds by changing the land use. In this setting, this assumption reflects the fact that it takes a long period of time to recuperate the forested land if the seller deviates via deforestation. Therefore the buyer will not be interested in trading with such a seller anymore as she does not have carbon sinks to offer. On the other hand, if the buyer deviates, the seller loses trust in the buyer and responds by changing the land use to a non-forest activity. Again, carbon sinks are lost along with the opportunity for future trade.

Additionally, parties cannot renegotiate the trading decision after carbon sinks are observed. The reason for this is that if a self-enforcing contract is optimal given any history, then the contract is strongly optimal. A strongly optimal contract has the property that parties cannot jointly gain from renegotiating a new self-enforcing contract even off the equilibrium path. Following the same argument as before, if either party deviates, carbon sinks are destroyed and with them the social surplus. Therefore there is no gain from renegotiation.

Finally, each period is played following a Nash equilibrium and parties use a stationary contract, in which the buyer always offers the same payment scheme, the seller always takes the same action, and the rents to the relationship are attractive enough for parties to self-enforce the contract and stay in the relationship (Baker et al., 1994; MacLeod, 2006; MacLeod and Malcomson, 1989, 1998). Moreover, repetition allows players to maintain a Sub-game Perfect Nash Equilibrium (SPNE) where parties honor the contract and maintain long-term relationships.

These assumptions allow for self-enforcing contracts — relational contracts — since they contain a complete plan for the relationship that describes behavior on and off the equilibrium path. On the equilibrium path, both parties fulfill the contract, the seller avoids deforestation and forest degradation and incurs the cost of forest conservation by spending the necessary time (effort) and making sure the forest remains intact to deliver the same carbon stocks from the baseline. If she decides to provide the carbon stock, at the delivery date, since the quantity is not verifiable by a third party, then the buyer has to decide to fulfill the initial agreement or to shirk. If the buyer honors the agreement he pays full payment $P_t(q_t) = p_t + b_t(q_t)$, gets the benefits of the carbon stocks and trade continues in the next period. If he decides to shirk then he can argue that the carbon sinks delivered are different from the baseline they agree on, and therefore pay $b_t(q_t) = 0$. If the seller breaches the contract, she does not incur in the cost of forest conservation and changes the land-use to a non-forest activity. Then, she receives p and the returns of the non-forest activity $\bar{u}$ and the buyer receives nothing. Lastly, if either party shirks, the parties break off trade forever.

2.1 Characterization of Self-enforcing Contracts

To overcome imperfect enforceability, the buyer offers a contract $y^* = \langle p, b(q) \rangle$ through which he provides additional incentives for the seller to avoid deforestation and forest degradation. The buyer pays p as a fixed payment regardless of what the seller's performance is, and the contingent payment takes the form of a bonus that the buyer promises to pay as long as the seller does not shirk. If the seller accepts the contract y^* , parties may renege without a formal penalty. The seller decides on how to use the land and it may differ from the buyer's desired use set forth in the contract. She can cooperate and choose $q_t \geq q^*$, or can shirk by choosing a non-forest activity.

Equality 3 gives the buyer's individual rationality constraint, IRC_b^m . The buyer participates in the REDD contract if the net benefits from such contract are greater than his alternative source of carbon reduction. In addition, the buyer's offer has to meet the seller's

individual rationality constraint, i.e., the offer has to provide a credible incentive to perform in each single period. This is given by equality 4, the seller's individual rationality constraint, IRC_s^m .

$$(3) \quad U_{bt}^m = V(q_t) - p_t - b(q_t) \geq \bar{\pi} \quad (IRC_b^m)$$

$$(4) \quad U_{st}^m = P(q_t) - c(q_t) \geq \bar{u} \quad (IRC_s^m)$$

Because of the imperfect enforcement a dynamic incentive compatibility constraint (DICC) for each party has to be fulfilled to self-enforce the contracts. The DICC is necessary to reach the optimal contract because it requires the parties to prefer to behave according to the contract instead of reneging. The seller's and the buyer's DICC are given by (5) and (6) respectively.

$$(5) \quad \frac{p + b(q) - c(q)}{1 - \delta} \geq p - c(q) + \frac{\bar{u}}{1 - \delta} \quad (DICC_s^m)$$

$$(6) \quad \frac{V(q) - p - b(q)}{1 - \delta} \geq V(q) - p + \frac{\delta}{1 - \delta} \bar{\pi} \quad (DICC_b^m)$$

A seller cooperates if and only if (5) is satisfied. The left hand side of (5) is the discounted payoff of the seller for cooperating and maintaining the carbon stock $q_t \geq q^*$ at the end of each date t . It represents the discounted gains from the relationship for the seller. She receives p during period t and the contingent payment $b(q)$ after delivering the carbon stocks established in the contract and she incurs the forest conservation costs. The right hand side represents the payoff if she shirks. Note that the most profitable deviation for the seller is to change the land-use and to not incur in any cost for forest conservation but in this case the principal, after observing the carbon stocks delivered, does not pay the bonus. If the seller does so, she incurs $c(q)$, receives the p and changes the land use to an alternative activity. Therefore, she collects the benefits from the alternative activity starting in period $t = 0$ and therefore, receives the present value of the returns from the non-forest activity for all periods.

Additionally, participation for the buyer in the long-term relationship is optimal if his DICC given by (6) is satisfied. A buyer cooperates if and only if the left hand side payments from cooperation are greater than the right hand side payments from deviation. If he co-

operates he gets the long-term benefits of the carbon stocks delivered net of the payments he makes. If he deviates he gets the benefits of the carbon storage minus what he paid upfront. Then in all future periods, he guarantees himself the benefits of the alternative options for carbon credits. Since both parties can deviate from the contract, the contingent payment must be sufficient to ensure a self-enforcing contract. It follows that the compensation scheme is bounded by the future gains of the relationship.

The buyer's optimization program is given by

$$\begin{aligned}
(7) \quad & \max_{p, b(q), q} \left(\frac{V(q) - p - b(q)}{1 - \delta} \right) \\
& \text{subject to} \quad P(q) - c(q) \geq \bar{u}, \\
& \quad \quad \quad \frac{p + b(q) - c(q)}{1 - \delta} \geq p - c(\underline{q}) + \frac{\bar{u}}{1 - \delta}, \\
& \quad \quad \quad \frac{V(q) - p - b(q)}{1 - \delta} \geq V(q) - p + \frac{\delta}{1 - \delta} \bar{\pi}, \\
& \quad \quad \quad \text{and} \quad q \in [\underline{q}, \bar{q}].
\end{aligned}$$

The seller's IRC can be rearranged as equality (8) and because a profit maximizing buyer pays only as much as is needed to induce the seller to participate, then the IRC_s^m binds:

$$(8) \quad p = \bar{u} + c(q) - b(q)$$

and expression (5) can be restated as,

$$(9) \quad p \geq c(\underline{q}) + \frac{c(q) - c(\underline{q}) + \bar{u} - b(q)}{\delta}$$

which gives the lower bound on the fixed payment, p , for inducing long-term seller cooperation. The presence of the performance payment allows the buyer to offer a lower fixed payment. By substituting (8) in (9), the optimal distribution of the total compensation among the fixed payment and the performance bonus is established. The optimal stationary REDD contract is defined in Proposition (1).

Proposition 1. *If parties are purely profit maximizing agents that trade repeatedly and contract enforcement is imperfect, assuming δ high enough, an optimal stationary REDD contract $\langle p^*, b^*(q^*) \rangle$ implements forest conservation, $\bar{q}$, by satisfying IRC_s^m , IRC_b^m , $DICC_s^m$*

and $DICC_b^m$, where IRC_s^m and $DICC_b^m$ bind, and the compensation scheme is given by:

$$(10) \quad b(q) \geq c(q) + \bar{u} ,$$

$$(11) \quad p \leq 0 , \text{ and}$$

$$(12) \quad P(q) = \bar{u} + c(q).$$

Proof. See appendix □

Equality (12) identifies the total compensation that the buyer offers the seller in the contract. Equality (11) gives the maximum fixed payment that the seller receives during date t and equality (10) gives the minimum bonus that the buyer promises to pay at the end of the period to induce the seller to not change the land-use.

Recalling the assumptions about the cost of forest conservation, $c(\underline{q}) = 0$, the fixed payment included in the optimal REDD contract equals zero. That means that under the optimal relational contract the seller does not get paid anything upfront or during the time she is under the contract until the end of the period. The contingent payment includes the complete payment to the seller. It includes the cost of providing optimal forest conservation and the opportunity cost of the alternative land use. This is intuitive because the seller knows that if she deviates from the contract and changes the use of land, the buyer does not pay the performance payment and furthermore he does not do business again with her. As a consequence she cannot get any future benefits from the relationship. This happens even with the smallest change in the land use as the carbon sinks differ from the baseline established at the beginning of the period and renegotiation is not possible under the assumptions of the optimal relational contract. Therefore, if the seller deviates from the contract she chooses the most profitable actions which include not incurring any cost for forest conservation and converting all land to agricultural or timber activities. Because an up-front fixed payment does not give incentives to the seller to remain in the relationship as it is not conditioned on performance, the buyer needs to provide enough additional incentives to the seller to perform under imperfect verifiability of carbon sinks. Moreover, because the contingent payments are limited by the future gains from the relationship and because the buyer's utility decreases when the fixed payment is positive, then all compensation is shifted to the contingent payment so that the seller has enough incentives to perform. The result is highlighted in the following corollary.

Corollary 2.1. *For imperfect enforcement regimes when parties are purely profit maximizers, all compensation is paid as a performance payment upon delivery of the carbon sinks, and*

the payment is weakly increasing in the returns of alternative activities and the full cost of forest conservation.

The total compensation is weakly increasing in the returns of non-forest activities and the cost of forest conservation because the contingent payment is limited by the gains from the relationship. If the returns from other activities or the cost of conserving the land are too high, then the future gains from the relationship may not be enough to provide enough incentives to the parties to perform and self-enforce the contract. Furthermore, the payment in the contract represents the cost of forest conservation under a REDD contract.

2.2 Sustainability of Self-enforcing Contracts

Self-enforcing contracts are sustainable if parties find that the optimal strategy is to cooperate in every period. The cooperation decision depends on each party's discounted payoff stream from the contract. The discounted payoff stream represents the value of the relationship and depends on how much each party values the future relative to the present (discount factor). If parties hold a very low discount factor, δ near to zero, the value of the relationship shrinks and it becomes less attractive to comply with the obligations of the contract. Therefore, it is more difficult to sustain cooperation and enforce contracts privately. As a consequence, social efficiency is potentially offset by the lack of formal enforcement.

In the case of the optimal REDD contract described in Proposition 1, parties find cooperation (self enforcement) to be the best strategy if they value the future relationship enough. The valuation is given by each party's dynamic incentive compatibility constraints. Combining the dynamic constraints for both parties given by (5) and (6) yields the discount factor necessary to achieve cooperation under the optimal REDD contract.

Proposition 2. *Let $\underline{\delta}^m > 0$. Cooperation under the optimal REDD contract is achievable $\forall \delta \in [\underline{\delta}^m, 1)$, where $\underline{\delta}^m = \frac{c(q)+\bar{u}}{V(q)-\bar{\pi}}$.*

Proposition 2 reports the range of discount factors that can support a cooperative equilibrium under the optimal REDD contract when parties are purely self-centered. It predicts that parties that have a discount factor greater or equal to the parameter $\underline{\delta}^m$ will cooperate in the REDD context. The term in the numerator includes the total payment the buyer has to make to the seller to avoid carbon emissions from deforestation and forest degradation. The payment represents the full cost of forest conservation under a REDD contract. The denominator represents the value of the carbon sinks from the contract. That

is, the value of the carbon sinks under contract for the buyer net of the outside option to get carbon credits from an alternative source. Then, $\underline{\delta}^m$ is the ratio of the total cost of forest conservation to the net value of the carbon sinks derived from the same forest conservation.

The higher the total payment is relative to the net value of the carbon sinks in the contract the closer to one is the discount factor needed to maintain cooperation. As a consequence, only parties who value the future nearly as much as the present find cooperation to be the optimal strategy.

A high discount factor threshold emerges when it is too costly for the seller to conserve the forest or if the returns of the non-forest activity are too high. The latter implies a higher opportunity cost for the land use which also relates to the seller's cost of forest conservation. This happens because the land becomes more attractive to other parties who will try to get the returns of the non-forest activity. Therefore, it will be more costly for the seller to make sure the forest land is not deforested or degraded by other parties.

On the other hand, for any given REDD payment, when the benefit that the buyer accrues from the carbon sinks delivered by the contract is similar to the benefits of getting carbon credits from other alternative sources, the discount factor needed for cooperation is also very high and cooperation is harder to sustain. Accordingly, contract sustainability requires that both parties have sufficiently high discount factors to prevent any party from shirking on contract obligations and to continue cooperation.

In contrast, the lower the cost of forest conservation is relative to the difference of returns from the carbon delivered under the contract and the alternative source of carbon credits, the smaller is the discount factor needed for contract self-enforcement. In these situations, REDD contracts are more likely to achieve their objective.

If parties have a discount factor such as $\delta > \underline{\delta}^m$, they repeatedly trade. The seller gets the discounted value of her outside opportunity (14) while the buyer gets the discounted value of the net social surplus (15).

$$(13) \quad U_s^m = \frac{V(q) - c(q) - \bar{u}}{(1-\delta)},$$

$$(14) \quad U_b^m = \frac{\bar{u}}{(1-\delta)}.$$

3 Social Preferences and Warm-Glow in Relational REDD Contracts

In this section I assume that parties are not only motivated by material self interest. The participants' utility function does not only depend on their own material payoff, but parties may also be concerned about the material resources the trading partner receives or may have some preferences for forest conservation. I assume that each party has perfect knowledge of the other's party's utility function so that there are no issues related to asymmetric information about parties' types. Given these alternative preferences, the buyer and the seller are assumed to behave rationally. I use three models applied in the literature to analyze social preferences and taste for conservation in the context of REDD relational contracts.

The first model includes social preferences by allowing the parties' utility functions to be either monotonically increasing or decreasing in the well-being of the other party, i.e. altruism and spite (Andreoni, 1989; Andreoni and Miller, 2002; Charness and Rabin, 2002; Cox et al., 2001; Levine, 1998). The second model also includes social preferences by assuming that parties are averse to inequality (Bolton and Ockenfels, 2000; Charness and Rabin, 2002; Fehr and Schmidt, 1999). In the third model parties are assumed to get a "warm-glow" from participating in activities related to climate goals achievement (Andreoni, 1989, 1990, 1993; Andreoni and Miller, 2002; Videras and Ann L. Owen, 2006). In the next sections, I analyze when either party or both parties act according these preference models.

3.1 Altruism and Spite in Relational REDD Contracts

In this section I assume that the either or both agents are altruistic or spiteful towards the other agent by having their utility strictly increasing or decreasing with the well being of the other party. For example some agencies such as the Forest Carbon Partnership Facility of the World Bank and The United Nations Collaborative Program on Reducing Emissions from Deforestation and Forest Degradation in Developing Countries have objectives that include economic development of the participants in developing countries and therefore their utility functions can be thought of as being increasing function of sellers' payments. In contrast purely selfish buyers, perhaps representing private companies engaged in emissions abatement, may only care about internal profit maximization. In addition, the buyer may value the material payoff of the seller negatively (spite). An example of this may be the case in which the seller is a corrupted government or a strong elite that owns the forested land and the buyer may dislike doing business with them.

On the other hand, the seller may have some sympathy for the objectives that a NGO such as Conservation International may have about conservation, and therefore the NGO's payoff has some positive weight into the seller's utility. Or, the agent may get disutility from the benefits a corrupted government may have from carbon sequestration contracts.

I assume that the buyer's utility is given by $U_{bt}^a = V(q_t) - P_t(q_t) + a_b U_{st}^m$, where a_b is a parameter that represents the buyer's utility weight on the utility of the seller.⁴ If $a_b = 0$, the buyer only cares about his own payoff and acts as a purely self-interested agent as in the previous section. If $a_b > 0$ the buyer acts according to altruistic reciprocity because his utility increases with the well being of the seller. Finally, if $a_b < 0$, the buyer's utility function decreases with the well-being of the seller. By the same token, the seller's utility is given by $U_{st}^a = P_t(q_t) - c(q_t) + a_s U_{bt}^m$, where a_s represents the seller's utility weight on the utility of the buyer and has the same effect that a_b has on the buyer's utility function.

Case 1: Altruistic buyer and self-interested seller

If the buyer acts altruistically and the agent continues to be self-interested, then $a_s = 0$ and the seller's IRS_s^m and $DICC_s^m$ remain the same while the buyer's IRC is now given by

$$(15) \quad U_{bt}^a = V_t(q_t) - P_t(q_t) + a_b U_{st} \geq \bar{\pi} \quad (IRC_b^a).$$

Furthermore, the buyer's $DICC$ also changes reflecting the buyer's altruistic preferences and it is given by

$$(16) \quad \frac{V_t(q_t) - P_t(q_t) + a_b \bar{U}_{st}^m}{1 - \delta} \geq V(q) - p + a_b \underline{U}_{st}^m + \frac{\delta}{1 - \delta} \bar{\pi} \quad (DICC_b^a).$$

On the left hand side, the modified buyer's $DICC$ reflects his payoff if parties cooperate. In this case, the buyer receives the material payoff from the contract and additional utility derived from the seller's payoff under the contract $\bar{U}_{st}^m$. On the right hand side, the $DICC_b^a$ reflects the buyer's utility when he deviates, in which case, he gets the returns from the carbon offsets net of the enforced payment and his utility is also affected by the utility that the seller gets when the buyer deviates, $\underline{U}_{st}^m$. $\underline{U}_{st}^m$ represents true altruism because the buyer benefits from the seller's utility even if he deviates.

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⁴This expression was first used by Edgeworth (1881) who referred to it as a coefficient of sympathy. It has been used by various authors to include altruism and spite in public goods models, other-regarding preference models and interdependent preference models. Examples of this are Anderson et al. (1998), Andreoni and Miller (2002), and Levine (1998).

Consequently, a buyer that acts according to altruistic reciprocity derives the optimal self-enforcing contract by maximizing his long term utility:

$$\begin{aligned}
(17) \quad & \max_{p, b(q), q} \left(\frac{V_t(q_t) - P_t(q_t) + a_b U_{st}^m}{1 - \delta} \right) \\
& \text{subject to} \quad P(q) - c(q) \geq \bar{u}, \\
& \quad \frac{p + b(q) - c(q)}{1 - \delta} \geq p - c(\underline{q}) + \frac{\bar{u}}{1 - \delta}, \\
& \quad \frac{V_t(q_t) - P_t(q_t) + a_b \bar{U}_{st}^m}{1 - \delta} \geq V(q) - p + a_b \underline{U}_{st}^m + \frac{\delta}{1 - \delta} \bar{\pi}, \\
& \text{and} \quad q \in [\underline{q}, \bar{q}].
\end{aligned}$$

Following the same steps as in section 2.1, I solve for the optimal contract in the presence of an altruistic buyer and a self-interested seller. A buyer who acts according to altruistic reciprocity offers the optimal stationary REDD contract defined in Proposition (3).

Proposition 3. *An altruistic principal offers an optimal stationary REDD contract $y^* = \langle p^*, b^*(q^*) \rangle$ that implements conservation of the forest land $\bar{q}$, and satisfies IRC_s^m , $DICC_s^m$, IRC_b^a and $DICC_b^a$, where IRC_s^m and $DICC_b^a$ bind. The compensation scheme is given by*

$$\begin{aligned}
(18) \quad & b(q) \geq c(q) + \bar{u} , \\
(19) \quad & p \leq 0 , \text{ and} \\
(20) \quad & P(q) = \bar{u} + c(q).
\end{aligned}$$

As expected, the contract is structured in the same way as in the presence of purely profit-maximizing parties because the seller's preferences have not changed. She needs the same incentive structure to perform. As a consequence, regardless of the preferences the buyer may have (self-interested or altruistic), the optimal REDD contract has the same characteristics: a fixed payment no greater than zero and a performance payment that contains the entire payment including the cost of forest conservation and the value of the alternative economic activity for the seller. In other words, no matter how sympathetic the buyer is toward the seller, it never results in an upfront payment or a larger bonus.

Once again, the contract is self-enforcing if parties find cooperation to be the best strategy. Proposition (4) addresses the conditions for self-enforcement.

Proposition 4. *Let $\delta^{a^b} > 0$. Cooperation among an altruistic buyer and a self-interested seller under the optimal REDD contract is achievable $\forall \delta \in [\delta^{a^b}, 1)$, where $\delta^{a^b} = \frac{(c(q) + \bar{u})(1 - a_b)}{V(q) - \bar{\pi} - a_b c(q)}$.*

Proposition 4 reports the range of discount factors that can support a cooperative equilibrium under the optimal REDD contract when the buyer is altruistic. It predicts that parties that have a discount factor greater than or equal to the parameter $\underline{\delta}^{a^b}$ cooperate in the REDD contract. The term in the numerator includes the total payment the buyer has to make to the seller to avoid carbon emissions net of the buyer's altruistic value of the payment. The denominator represents the buyer's altruistically adjusted net benefit of the carbon sinks from the contract.

Similar to when both parties are purely self-interested, a high discount factor is needed when it is too costly for the seller to conserve the forest or if the returns of the non-forest activity are too high. However, with an altruistic buyer, the discount factor is inversely related to the parameter of altruism as $\partial \underline{\delta}^{a^b} / \partial a_b < 0$. The overall result is that the more altruistic the buyer is, the wider the range of discount factors that sustains cooperation because the threshold for cooperation is lower. Table 1 summarizes the results and compares them to the purely self-interested agent case.

The wider range of discount factors reflects the increase in the per period payoff from altruism that an altruistic buyer gets with respect to the per period payoff of a self-interested buyer. An altruistic buyer gets the altruistic value of the seller's payoff in addition to the payoff of a purely self-interested buyer. Then, the more altruistic the buyer is, the higher the overall per period payoff he gets. Therefore, even with a lower discount factor, the discounted stream of benefits from cooperation is more attractive than the benefits from deviation. That is, the increase in the per period payoff overcomes a lower valuation of the future, reflected in a lower discount factor, and therefore cooperation can be sustained for a wider range of discount factors. If cooperation is the case, parties repeatedly trade. The seller gets the discounted value of her outside opportunity (24) while the buyer gets the discounted value of the net social surplus adjusted for his altruism (23). The buyer's altruism gives him higher utility than if he were only to value material payoffs.

$$(21) \quad U_s^m = \frac{V(q) - c(q) - \bar{u}(1 - a_b)}{(1 - \delta)},$$

$$(22) \quad U_b^m = \frac{\bar{u}}{(1 - \delta)}.$$

Case 2: Spiteful buyer and self-interested seller

Now assume that the buyer gets disutility from the seller's payoffs, ($a_b < 0$), which reflects a spiteful buyer. The buyer's IRC and DICC remain the same but now a_b is negative. These preferences can reflect the case in which either the contracts are implemented or the

contracted land rights belong to a corrupted government, therefore the buyer dislikes the profits the seller gets. As the seller's IRC and DICC have not changed, the payments are going to be the same as in the case of an altruistic buyer, however, the spitefulness is going to be reflected in the long term cooperation opportunities.

Proposition 5. *Let $\underline{\delta}^{s^b} > 0$. Cooperation among a spiteful buyer and a self-interested seller under the optimal REDD contract is achievable $\forall \delta \in [\underline{\delta}^{s^b}, 1)$, where $\underline{\delta}^s = \frac{(c(q)+\bar{u})(1+a_b)}{V(q)-\bar{\pi}+a_b c(q)}$.*

The term in the numerator includes the total payment to the seller for avoiding carbon emissions adjusted by the buyer's spite towards the seller's material payoffs. The denominator represents the spite-adjusted net benefit of the carbon sink from the contract. It is easy to see that with an spiteful buyer, the discount factor is directly related to the parameter of spite as $\partial \underline{\delta}^{s^b} / \partial a_b > 0$. Then, the more spiteful the buyer is, the narrower the range of discount factors that sustains cooperation because the threshold for cooperation is higher. The explanation for this is that a spiteful buyer gets a lower per period payoff compared to a purely self-interested buyer. The more spite the buyer feels, the lower the per period utility he gets, therefore he needs a higher discount factor so that the value of the long-term benefits from cooperation remain higher than the benefits from deviation. As a consequence, cooperation is more difficult to maintain. Nevertheless, if parties cooperate, the seller gets the discounted value of her outside opportunity (27) while the buyer gets the discounted value of the net social surplus adjusted for his spite (26). The buyer receives the same material payoff but his spite towards the seller gives him lower utility than if he were only to value material payoffs.

$$(23) \quad U_s^m = \frac{V(q) - c(q) - \bar{u}(1+a_b)}{(1-\delta)},$$

$$(24) \quad U_b^m = \frac{\bar{u}}{(1-\delta)}.$$

Case 3: Altruistic seller and self-interested buyer

Consider the case in which only the seller acts altruistically and the buyer continues to be self-interested, then, $a_s > 0$, $a_b = 0$ and the buyer's *IRS* and *DICC* remain the same IRS_b^m and $DICC_b^m$, while the seller's *IRC* is given by

$$(25) \quad U_{st}^a = P_t(q_t) - c(q_t) + a_s U_{bt}^m \geq \bar{u} \quad (IRC_s^a).$$

Furthermore, the seller's $DICC_s^a$ also changes reflecting the seller's altruistic preferences and

it is given by

$$(26) \quad \frac{P_t(q_t) - c(q_t) + a_s \bar{U}_{bt}^m}{1 - \delta} \geq p - c(\underline{q}) + a_s \underline{U}_{bt}^m + \frac{\bar{u}}{1 - \delta} \quad (DICC_s^a).$$

An example of this may be the case in which the seller is sympathetic to the buyer's objectives such as conservation objectives that a NGO such as Conservation International may have. In this case, the self-interested buyer solves the following maximization program:

$$(27) \quad \begin{aligned} \max_{p, b(q), q} & \left(\frac{V_t(q_t) - P_t(q_t)}{1 - \delta} \right) \\ \text{subject to} & \quad P_t(q_t) - c(q_t) + a_s \bar{U}_{bt}^m \geq \bar{u}, \\ & \quad \frac{P_t(q_t) - c(q_t) + a_s \bar{U}_{bt}^m}{1 - \delta} \geq p - c(\underline{q}) + a_s \underline{U}_{bt}^m + \frac{\bar{u}}{1 - \delta}, \\ & \quad \frac{V_t(q_t) - P_t(q_t)}{1 - \delta} \geq V(q) - p + \frac{\delta}{1 - \delta} \bar{\pi}, \\ & \quad \text{and} \quad q \in [\underline{q}, \bar{q}]. \end{aligned}$$

Because a profit-maximizing buyer only offers a payment that ensures the acceptance of the seller, the seller's IRC_s^a can be rearranged as

$$(28) \quad p = \frac{\bar{u} + c(q) - a_s V(q_t) - b(q)(1 - a_s)}{1 - a_s}$$

and expression $DICC_s^a$ can be restated as,

$$(29) \quad p \geq \frac{c(q) + \bar{u} - (1 - a_s)b(q) - a_s V(q) + (1 - \delta)(a_s V(\underline{q}) - c(\underline{q}))}{\delta(1 - a_s)}$$

which gives the lower bound on the fixed payment, p , for inducing long-term seller cooperation. By substituting (27) in (28), the optimal distribution of the total compensation among the fixed payment and the performance bonus is established. The optimal stationary REDD contract in this case is defined in Proposition 6.

Proposition 6. *If contract enforcement is imperfect and the seller is altruistic, and assuming δ high enough, a self-interested principal offers an optimal stationary REDD contract $\langle p^*, b^*(q^*) \rangle$ that implements forest conservation, $\bar{q}$, by satisfying IRS_s^a , IRS_b^s , $DICC_s^a$, and*

$DICC_b^m$, where IRS_s^a and $DICC_b^m$ bind, and the compensation scheme is characterized by:

$$(30) \quad b(q) \geq \frac{c(q) + \bar{u} - a_s(V(q))}{1 - a_s},$$

$$(31) \quad p \leq 0, \text{ and}$$

$$(32) \quad P(q) = \frac{\bar{u} + c(q) - a_s V(q)}{1 - a_s}$$

Equality (32) identifies the total compensation that a buyer has to offer to an altruistic seller in the contract. Equality (31) gives the base payment that the seller receives during date t and equality (30) gives the size of the bonus that the buyer promises to pay at the end of the period to induce the seller to not change the land-use.

The total payment and both the base and performance payments are decreasing in the seller's coefficient of altruism. Recalling the assumptions about the cost of forest conservation, $c(\underline{q}) = 0$ and the carbon benefits from changing the land use, $V(\underline{q}) = 0$, the base payment included in the optimal REDD contract for an altruistic seller also equals zero. That means that regardless of the seller's preferences, under the optimal relational contract the seller does not get paid anything upfront or during the time she is under the contract until the end of the period. The contingent payment includes the complete payment to the seller. It includes the cost of providing optimal forest conservation and the opportunity cost of the alternative land use.

In the case of the optimal REDD contract in the presence of an altruistic seller, parties find cooperation (self enforcement) to be the best strategy if they value the future relationship at least as much as the discount factor described in Proposition 7.

Proposition 7. *Let $\delta^{a^s} > 0$. Cooperation under the optimal REDD contract is achievable $\forall \delta \in [\underline{\delta}^{a^s}, 1)$, where $\underline{\delta}^{a^s} = \frac{c(q) + \bar{u} - a_s(V(q) - V(\underline{q}))}{V(q) - \bar{\pi} - a_s(V(q) - V(\underline{q}) - \bar{\pi})}$.*

Proposition 7 reports the range of discount factors that can support a cooperative equilibrium under the optimal REDD contract when an altruistic seller and a self-interested buyer trade. The term in the numerator includes the total payment the buyer has to make to the seller to avoid carbon emissions net of the seller's altruistic value for the buyer's benefits. The denominator represents the buyer's net benefit of the carbon sinks from the contract adjusted by the seller's altruistic parameter. With an altruistic seller, the discount factor is also inversely related to the parameter of altruism as $\partial \underline{\delta}^{a^s} / \partial a_s < 0$. The overall result is analogous to the case with an altruistic buyer; the more altruistic the seller is, the wider the range of discount factors that sustains cooperation because the threshold for cooperation is

lower.

As with an altruistic buyer, the wider range of discount factors reflects the increase in the per period payoff from altruism that an altruistic seller gets with respect to the per period payoff of a self-interested seller. Then, the more altruistic the seller is, the lower the payment she is willing to accept. The lower payment increases the buyer's monetary payoff, resulting in a lower discount factor needed for cooperation. Even with a lower discount factor, the discounted stream of benefits from cooperation is more attractive than the benefits from deviation. That is, the increase in the per-period payoff overcomes a lower valuation of the future, reflected in a lower discount factor, and therefore cooperation can be sustained for a wider range of discount factors.

If parties cooperate, the seller gets a lower material payoff than if she were purely self-interested. However, the seller receives the discounted value of her outside opportunity (37) because the utility derived from altruism compensates for the lower payment. The buyer gets the discounted value of the net social surplus adjusted for the seller's altruism (36). The buyer receives a higher material payoff than if the seller were self-interested because he is able to pay less.

$$(33) \quad U_b^{a^s} = \frac{V(q) - c(q) - \bar{u}}{(1 - a_b)(1 - \delta)},$$

$$(34) \quad U_s^{a^s} = \frac{\bar{u}}{(1 - \delta)}.$$

Case 4: Spiteful seller and self-interested buyer

Let's assume that the seller gets disutility from the payoffs that the buyer gets, then $a_s < 0$, which reflects a spiteful seller. This case can reflect when the buyer is a corrupted government that traditionally has given rents to an elite group. Therefore, the seller dislikes the profits the buyer makes from carbon sequestration. The maximization program is the same as (26) but now a_s is negative. The next proposition states the optimal contract in the presence of a spiteful seller and a self-interested buyer.

Proposition 8. *If contract enforcement is incomplete and the seller is spiteful, assuming $\delta \geq \underline{\delta}^s$, a self-interested buyer offers an optimal stationary REDD contract $\langle p^*, b^*(q^*) \rangle$ that implements conservation of the forest land $\bar{q}$, which satisfies IRC_s^s , $DICC_s^s$, IRS_b^m , and*

$DICC_b^m$, where IRS_s^s and $DICC_b^m$ bind, and the compensation scheme is characterized by:

$$(35) \quad b(q) \geq \frac{c(q) + \bar{u} + a_a(V(q))}{1 + a_a} ,$$

$$(36) \quad p \leq 0 , \text{ and}$$

$$(37) \quad P(q) = \frac{\bar{u} + c(q) + a_a V(q)}{1 + a_a}$$

and cooperation is achievable $\forall \delta \in [\underline{\delta}^{ss}, 1)$, where $\underline{\delta}^{ss} = \frac{c(q) + \bar{u} + a_a V(q)}{(1 + a_a)(V(q) - \bar{\pi})}$.

Proposition 8 presents the total payment and its structure given a spiteful seller and a self-interested buyer. It is easy to see that all payments are increasing in the seller's spite coefficient. That is the more spite the seller feels towards the buyer, the higher the total compensation needs to be for the seller to participate and engage in a long-term relationship. Although the fixed payment is also increasing in the spite coefficient, giving the assumptions of the model, it equals zero while the bonus contains all payments.

Additionally the seller's spite is also reflected in the long-term cooperation opportunities. It is easy to see that with an spiteful seller, the discount factor is directly related to the parameter representing spite as $\partial \underline{\delta}^{ss} / \partial a_s > 0$. The more spiteful the agent is, the narrower the range of discount factors that sustains cooperation because the threshold for cooperation is higher. The intuition in this case is similar to the case of a spiteful buyer. An spiteful seller gets a lower per-period payoff when compared to payoffs derived only from material resources. Therefore, she needs a higher payment to compensate the utility loss she gets from the buyer's material gains. As a consequence the buyer gets lower payoffs from the relationship and as a consequence a higher discount factor is needed.

If parties cooperate, the seller gets a higher material payoff than if she were purely self-interested. However, the seller receives the same discounted value of her outside opportunity (44) because of the disutility derived from spite. The buyer gets the discounted value of the net social surplus adjusted for the seller's spite (43). The buyer receives lower material payoff than if the seller were self-interested because he has to pay a higher compensation to induce a spiteful seller to participate.

$$(38) \quad U_s^{ss} = \frac{V(q) - c(q) - \bar{u}}{(1 + a_b)(1 - \delta)} ,$$

$$(39) \quad U_b^{ss} = \frac{\bar{u}}{(1 - \delta)} .$$

3.2 Inequality Aversion and Relational REDD Contracts

Fehr and Schmidt (1999) developed a theory of fairness in which they assume that a fair

participant is altruistic towards other participants if his or her material payoffs are less than equal, but the fair participant also feels envy when the other participants' material payoffs is greater than half. In this section, I analyze the cases in which the buyer and / or the seller are characterized by such a dislike of advantage or disadvantage. I assume for simplicity that the reference agent for each party is the agent with whom they contract. In this case, the reference agent for the seller is the buyer and vice versa. To capture this idea, I consider the following utility functions for the buyer and seller respectively.

$$(40) \quad U_b^{IA}(x_s, x_b) = V(q) - P(q) - \alpha_b \max\{x_s - x_b, 0\} - \beta_b \max\{x_b - x_s, 0\}$$

$$(41) \quad U_s^{IA}(x_s, x_b) = P(q) - c(q) - \alpha_s \max\{x_b - x_s, 0\} - \beta_s \max\{x_s - x_b, 0\}$$

where $\beta_i \leq \alpha_i$ and $0 \leq \beta_i \leq 1$. The parameter α_i weights the utility loss from inequality to i 's disadvantage, while the parameter β_i weights the loss in utility from advantaged inequality. x_s and x_b represent the material payoffs for the seller and the buyer respectively, where $x_s = U_s^m = P(q) - c(q)$ and $x_b = U_b^m = V(q) - P(q)$ and $P(q)$ determines the share of the total surplus, $S(q) = V(q) - c(q)$, that each party gets. In addition, $x_b - x_s = V(q) + c(q) - 2P(q)$ and $x_s - x_b = 2P(q) - V(q) - c(q)$.

For any given payment, the fair party prefers a quality level that equalizes the material payoffs for both parties. That means to maximize either function, for a fair buyer or a fair seller or both, the material payoff for the seller should be equal to the buyer's material payoffs. Then, when maximizing a fair minded party's function $x_b = x_s$ holds. Solving for the total payment and differentiating with respect to q , we get that $x_b = x_s$, $U_b = U_s$, $V(q) - P(q) = P(q) - c(q)$ and

$$(42) \quad P(q) = \frac{V(q) + c(q)}{2}$$

$$(43) \quad \frac{\partial P(q)}{\partial q} = \frac{\frac{\partial V(q)}{\partial q} + \frac{\partial c(q)}{\partial q}}{2}.$$

Rearranging (43) I obtain how the quality level changes with respect to the change in the total compensation: $\frac{\partial q}{\partial P(q)} = \frac{2}{V'(q) + c'(q)}$. This implies that higher the total payment, the higher the quality provision.

If the buyer is of a fair type, he offers a compensation that equals $P(q) = \frac{V(q) + c(q)}{2}$. If the seller is of a self-interested type, she accepts the contract if the compensation, $P(q) = \frac{V(q) + c(q)}{2}$, gives her a payoff such that $U_s^m \geq \bar{u}$. If the seller is the one that is of a fair type and the buyer is self-interested, the buyer has to offer a contract that gives the seller a payoff

at least as great as $\bar{u}$ and provides a quality level that equalizes the each party's material payoffs. Therefore, if at least one of the parties is of the fair type, the compensation has to reflect equal material payoffs for the parties. Additionally, for both types to cooperate in the long-term relationship, the gains from cooperation need to be greater than the gains from deviation. In this case, the DICC's are the same as $DICC_s^m$ and $DICC_b^m$.

If either party is of a fair type the buyer solves the following maximization problem:

$$\begin{aligned}
(44) \quad & \max_{p, b(q), q} \left(\frac{V(q) - P(q)}{1 - \delta} \right) \\
& \text{subject to} \quad P_t(q_t) = \frac{V(q) + c(q)}{2}, \\
& \quad \quad \quad P_t(q_t) - c(q) \geq \bar{u}, \\
& \quad \quad \quad \frac{P_t(q_t) - c(q_t)}{1 - \delta} \geq p - c(\underline{q}) + \frac{\bar{u}}{1 - \delta}, \\
& \quad \quad \quad \frac{V_t(q_t) - P_t(q_t)}{1 - \delta} \geq V(q) - p + \frac{\delta}{1 - \delta} \bar{\pi}, \\
& \quad \quad \quad \text{and} \quad q \in [\underline{q}, \bar{q}].
\end{aligned}$$

If $P(q) = \frac{V(q) + c(q)}{2}$, then $\frac{V(q) + c(q)}{2} - c(q) \geq \bar{u}$ needs to be true for the seller to participate. This implies that $\frac{V(q) - c(q)}{2} \geq \bar{u}$ needs to be true. In other words, the total surplus needs to be high enough so that $V(q) - c(q) \geq 2\bar{u}$.

Now, solving the $DICC_s^m$ for p , we get the same lower bound for the base payment as the case with self-interested parties. By substituting $p = \frac{V(q) + c(q)}{2} - b(q)$, the structure of the total compensation of the optimal stationary REDD contract is derived and it is given in the next Proposition.

Proposition 9. *The optimal REDD contract, $\langle p^*, b^*(q^*) \rangle$, when the buyer and / or the seller are fair-type, implements forest conservation, $\bar{q}$, if δ is high enough, $S(q) \geq 2\bar{u}, S(q) \geq 2\bar{\pi}$, the $IRC_s^m, IRC_b^m, DICC_s^m, DICC_b^m$ and (35) are satisfied. The contract is given by:*

$$(45) \quad b(q) = \frac{c(q) + \bar{u}}{1 - \delta} - \frac{\delta(V(q) + c(q))}{2(1 - \delta)},$$

$$(46) \quad p = \frac{V(q) - c(q) - 2\bar{u}}{2(1 - \delta)}, \text{ and}$$

$$(47) \quad P(q) = \frac{V(q) + c(q)}{2}.$$

When the total surplus is such that $\frac{S(q)}{2} \geq \bar{u}$, the total payment in the presence of fair parties is higher than the total payment in the presence of purely selfish parties. By using this total payment, the buyer and the seller share equally the surplus. Recalling the assumptions about the cost of forest conservation, $c(\underline{q}) = 0$, the base payment included in the

optimal REDD contract, in the presence of fair parties, is greater than zero, which contrasts with the base payment in the case of purely selfish agents. In the presence of a fair buyer and / or a fair seller, the optimal relational contract pays the seller a positive upfront payment. In addition, the contingent payment that the buyer promises to pay is also higher than the case of purely self-interested agents. The result is highlighted in the following corollary.

Corollary 3.1. *For imperfect enforcement regimes in the presence of a fair minded buyer and / or seller, the total compensation is higher than the case of purely selfish agents. Both the performance payment and the base payment are also higher. The payment is weakly increasing in the returns to carbon credits and the cost of forest conservation.*

Even more, parties find cooperation (self enforcement) to be the best strategy if they value the future relationship as much as the threshold discount factor $\underline{\delta}^{IA}$ given in the next Proposition.

Proposition 10. *Let $\underline{\delta}^{IA} > 0$. Cooperation under the optimal REDD contract when parties are fair minded is achievable $\forall \delta \in [\underline{\delta}^{IA}, 1)$, where $\underline{\delta}^{IA} = \frac{c(q)+\bar{u}}{V(q)-\bar{\pi}}$.*

It is easy to see that $\underline{\delta}^{IA}$ is the same as the threshold for the discount factor for the case when both parties are selfish, or that $\underline{\delta}^{IA} = \underline{\delta}^m$. In conclusion, the presence of fair-minded agents only changes the distribution of surplus but not the range of discount factors for which the long-term relationship is sustained. The results are the same if only one party is fair-minded and the other one is selfish, or if both parties are fair-minded. In all cases, the long-term payoff for both parties are given by

$$(48) \quad U_s^{IA} = \frac{V(q)-c(q)}{2(1-\delta)},$$

$$(49) \quad U_b^{IA} = \frac{V(q)-c(q)}{2(1-\delta)}.$$

3.3 Warm-Glow and Relational REDD Contracts

So far, I have assumed that parties act according to purely selfish motives, altruism towards the trading partner's payoff or inequality aversion preferences. However, when parties decide to participate in activities related to carbon sequestration provision there are many factors influencing their decisions. In fact, parties may argue they care about climate change goals or environmental conservation as an altruistic motive, which implies that they receive utility from the value society gets from carbon sequestration. Nevertheless, agents may behave

according to “impurely altruistic” motives. As in the literature on contributions for privately provided public goods, agents may increase their utility by simply contributing to the achievement of environmental goals because of the prestige, friendship or respect that can be earned from the action.

In the context of charitable giving, Andreoni (1989, 1990) shows that agents have two motives for giving. First, each individual’s utility is indreasing in the level of provision of a public good. Therefore he demands and contributes more to the provision of the public good, a motivation known in the public goods literature as “altruism” (Becker, 1974). Second, agents experience an increase in their utility from giving per se, which is called a “warm-glow”. Warm-glow giving is identified as a selfish motive, therefore, a model of charitable giving that also includes warm-glow is considered as an impure altruistic model. In the case of carbon sequestration, parties may also experience warm-glow giving from participating in carbon sinks provision. In this section, I derive a the optimal relational contract when one or both parties have such preferences.

I assume that the parties care about their own monetary payoff derived from participating in carbon sequestration contracts, but they also receive a warm glow from contributing to climate change goals. Further I assume the warm glow is increasing in the amount of carbon sequestered. The new utility functions for the seller and the buyer are given by (55) and (56) respectively and they reflect what Andreoni (1989, 1990) calls “purely egoistic” preferences.

$$(50) \quad U_s^{WG} = P(q_t) - c(q_t) + g_s q_t, \quad (IRC_s^{WG})$$

$$(51) \quad U_b^{WG} = V(q_t) - P(q_t) + g_b q_t. \quad (IRC_b^{WG})$$

where g_s and g_b are the parameters of warm glow for the seller and buyer. If $g_i = 0$ the buyer and the seller only get utility from the material payoff derived from the conservation of carbon sinks. If $g_i > 0$, warm glow adds to each party’s utility function a term g_i times the amount of carbon sinks provided. For simplicity, I assume that the value $\underline{q}$ equals zero. Furthermore, the self-enforcing constraints are given now by

$$(52) \quad \frac{P_t(q_t) - c(q_t) + g_s q_t}{1 - \delta} \geq p - c(\underline{q}) + g_s \underline{q} + \frac{\bar{u}}{1 - \delta}, \quad (DICC_s^{WG})$$

$$(53) \quad \frac{V_t(q_t) - P_t(q_t) + g_b q_t}{1 - \delta} \geq V(q_t) - p + g_b q_t + \frac{\delta}{1 - \delta} \bar{\pi}. \quad (DICC_b^{WG})$$

In this case, the buyer solves the following program to obtain the optimal contract

under a warm-glow assumption:

$$\begin{aligned}
(54) \quad & \max_{p, b(q), q} \left(\frac{V(q) - P(q) + g_b q}{1 - \delta} \right) \\
& \text{subject to} \quad P_t(q_t) - c(q) + g_s q \geq \bar{u}, \\
& \quad \frac{P_t(q_t) - c(q_t) + g_s q_t}{1 - \delta} \geq p - c(\underline{q}) + g_s \underline{q} + \frac{\bar{u}}{1 - \delta}, \\
& \quad \frac{V_t(q_t) - P_t(q_t) + g_b q}{1 - \delta} \geq V(q) - p + g_b q + \frac{\delta}{1 - \delta} \bar{\pi}, \\
& \text{and} \quad q \in [\underline{q}, \bar{q}].
\end{aligned}$$

The lower bound of the base payment is obtained by rearranging $DICC_s^{WG}$: $p \geq \frac{c(q_t) - g_s q_t - c(\underline{q}) + g_s \underline{q} + \bar{u} - b(q)}{\delta} + c(\underline{q}) - g_s \underline{q}$. Because the buyer only pays as much as necessary to ensure seller participation, the IRS_s^{WG} binds and rearranging for p it becomes: $p = c(q) + \bar{u} - g_s q_t - b(q)$. Now substituting one in the other, the structure of the optimal contract is identical to that given in the next Proposition.

Proposition 11. *The optimal REDD contract, $\langle p^*, b^*(q^*) \rangle$, when the buyer and the seller have warm glow preferences, implements conservation of the forest land $\bar{q}$ if $\delta \geq \delta^{WG}$ and satisfies IRS_s^{WG} , IRS_b^{WG} , $DICC_s^{WG}$ and $DICC_b^{WG}$. The contract is characterized by:*

$$(55) \quad b(q) \geq c(q) - g_s q + \bar{u},$$

$$(56) \quad p \leq 0, \text{ and}$$

$$(57) \quad P(q) = c(q) + \bar{u} - g_s q.$$

$$\text{and } \underline{\delta}^{WG} = \frac{c(q) + \bar{u} - g_s(q - \underline{q})}{V(q) - \bar{\pi} + g_b q + g_s \underline{q}}.$$

Proposition 11 presents the total payment and payment structure under warm-glow preferences. The payment is independent of the buyer's warm glow coefficient, g_b , but it relates inversely to the seller's warm glow coefficient, g_s . The larger the carbon sink maintained, the lower the payment the seller accepts to participate and cooperate. This happens because the warm glow that the seller receives from an additional unit of carbon sequestered compensates the loss in utility she gets from a lower payment. By the same token, the more satisfaction a unit carbon sink gives the seller the lower the payment per unit of carbon she accepts as it compensates for the lower payment with warm glow.

From the first order conditions we get $V'(q) + g_b = c'(q) - g_s$ and by assumption we know that $V'(\cdot) > c'(\cdot) \forall q \in Q$, therefore, the highest level of forest conservation is always achieved in the presence of warm glow. Furthermore, parties cooperate if $\underline{\delta} \geq \underline{\delta}^{WG}$, and they

get $U_s = \bar{u}$ and $U_b = V(q) - c(q) - \bar{u} + q(g_s + g_b)$.

4 Final Analysis and Comments

Designing contracts to reduce emissions from deforestation and forest degradation is an important part of global climate change mitigation strategies. The use of self-enforcing contracts may provide enough incentives for parties to perform even with the institutional differences among the countries in which the contracts will be implemented. However, the structure and the sustainability of these contracts may vary depending on the objectives and preferences of the parties participating. In this paper, I have compared the structure of the optimal relational contract in the presence of purely self-interested participants to the optimal structure when participants are motivated by other preferences in addition to own material payoffs. Table 1 summarizes the models analyzed, each party's objective function, the individual rationality constraints and the dynamic enforcement constraints in each case for the buyer and seller respectively.

The benchmark case includes purely self-interested parties who only care about own material payoffs. The parties' objective functions change relative to the benchmark case to reflect altruism and spite by placing positive and negative weights upon the material payoffs gained by the other party while the other party remains purely self-interested. In the second case, the objective function changes relative to the benchmark to reflect inequality aversion by the parties. Then, parties maximize utility if parties receive equitable material payoffs from the relationship. Lastly, the objective functions also change by including utility gains from the warm glow of contributing to climate change goals. The individual rationality constraints and self-enforcement constraints also changed to reflect the new preferences with exception of the inequality aversion case in which in addition to the IRC and DICC the contract satisfies a equitable distribution of surplus.

Table 1 summarizes the results for each case. I find that when the buyer acts according to altruistic reciprocity or spite the optimal contracts offer identical incentives to the seller as in the benchmark case of self-interested parties - a payment scheme in which all remuneration for carbon sequestration is provided at the end of the contracting period as a bonus payment and no upfront payment is provided. However, if the buyer is inequality averse he compensates the seller such that she gets half of the surplus and the payment includes a positive fixed payment and a bonus no greater than the bonus paid when the buyer is self-interested. This latter result holds when the seller is averse to inequality or if

Table 1: Summary results

B-S Func-tion	Payment	Discount factor	Monetary payoffs (per period)	Total Utility (per period)
U_b^m, U_s^m	$P(q) = c(q) + \bar{u}$ $p = 0$ $b(q) = c(q) + \bar{u}$	$\delta \geq \underline{\delta}^m = \frac{c(q) + \bar{u}}{V(q) - \bar{\pi}}$	$U_b^m = V(q) - c(q) - \bar{u}$ $U_s^m = \bar{u}$	$U_b^m = V(q) - c(q) - \bar{u}$ $U_s^m = \bar{u}$
U_b^a, U_s^m	$P(q) = c(q) + \bar{u}$ $p = 0$ $b(q) = c(q) - c(q) + \bar{u}$	$\underline{\delta}^m > \underline{\delta}^{a^b} = \frac{(c(q) + \bar{u})(1 - a_b)}{V(q) - \bar{\pi} - a_b c(q)}$	$U_b^a = V(q) - c(q) - \bar{u}$ $U_s^m = \bar{u}$	$U_b^a = V(q) - c(q) - (1 - a_b)\bar{u}$ $U_s^m = \bar{u}$
U_b^m, U_s^m	$P(q) = c(q) + \bar{u}$ $p = 0$ $b(q) = (c(q) + \bar{u}) - c(q) + \bar{u}$	$\underline{\delta}^m \geq \underline{\delta}^{s^b} = \frac{(c(q) + \bar{u})(1 + a_b)}{V(q) - \bar{\pi} + a_b(c(q))}$	$U_b^s = V(q) - c(q) - \bar{u}$ $U_s^m = \bar{u}$	$U_b^s = V(q) - c(q) - (1 + a_b)\bar{u}$ $U_s^m = \bar{u}$
U_b^s, U_s^a	$P(q) = \frac{c(q) + \bar{u} - a_s V(q)}{1 - a_s}$ $p = 0$ $b(q) = \frac{c(q) + \bar{u} - a_s V(q)}{1 - a_s}$	$\underline{\delta}^m \geq \underline{\delta}^{a^s} = \frac{c(q) + \bar{u} - a_s V(q)}{V(q) - \bar{\pi} - a_s(V(q) - \bar{\pi})}$ $U_s^a = \frac{\bar{u} - a_s(V(q) - c(q))}{1 - a_s}$	$U_b^m = \frac{V(q) - c(q) - \bar{u}}{1 - a_s}$ $U_s^a = \frac{\bar{u} - a_s(V(q) - c(q))}{1 - a_s}$	$U_b^m = \frac{V(q) - c(q) - \bar{u}}{1 - a_s}$ $U_s^a = \bar{u}$
U_b^m, U_s^s	$P(q) = \frac{c(q) + \bar{u} + a_s V(q)}{1 + a_s}$ $p = 0$ $b(q) = \frac{c(q) + \bar{u} + a_s V(q)}{1 + a_s}$	$\underline{\delta}^m \geq \underline{\delta}^{s^s} = \frac{c(q) + \bar{u} + a_s V(q)}{V(q) - \bar{\pi} + a_s(V(q) - \bar{\pi})}$	$U_b^s = \frac{V(q) - c(q) - \bar{u}}{1 + a_s}$ $U_s^s = \frac{\bar{u} + a_s(V(q) - c(q))}{1 + a_s}$	$U_b^s = \frac{V(q) - c(q) - \bar{u}}{1 + a_s}$ $U_s^s = \bar{u}$
U_b^{IA}, U_s^{IA}	$P(q) = \frac{V(q) + c(q)}{2}$ $p = \frac{V(q) - c(q) - 2\bar{u}}{2(1 - \delta)}$ $b(q) = \frac{c(q) + \bar{u}}{(1 - \delta)} - \frac{\delta(V(q) + c(q))}{2(1 - \delta)}$	$\underline{\delta}^m \geq \underline{\delta}^{IA} = \frac{c(q) + \bar{u}}{V(q) - \bar{\pi}}$	$U_b^{IA} = \frac{V(q) - c(q)}{2}$ $U_s^{IA} = \frac{V(q) - c(q)}{2}$	$U_b^{IA} = \frac{V(q) - c(q)}{2}$ $U_s^{IA} = \frac{V(q) - c(q)}{2}$
U_b^{WG}, U_s^{WG}	$P(q) = c(q) + \bar{u} - g_s q$ $p = 0$ $b(q) = c(q) - g_s q + \bar{u}$	$\underline{\delta}^m \geq \underline{\delta}^{WG} = \frac{c(q) + \bar{u} - g_s q}{V(q) - \bar{\pi} + g_b q}$	$U_b^{WG} = V(q) - c(q) - \bar{u} + g_s q$ $U_s^{WG} = \bar{u} - g_s q$	$U_b^{WG} = V(q) - c(q) - \bar{u} + g_s q$ $U_s^{WG} = \bar{u}$

both parties hold such preferences.

If the seller is altruistic or holds warm-glow preferences, the optimal contract offers a lower total payment than the one necessary to motivate the seller when she is a purely profit maximizing agent. The fixed payment is zero while the bonus includes the value of the cost differential of forest conservation and the value of the alternative use of land less the altruistic or warm-glow value that the seller obtains. In these cases, the seller is willing to accept a lower payment because she is compensated in her payoffs by an altruistic or warm-glow value derived from participating in the contract. If instead, the seller feels spite towards the buyer, the optimal contract provides a higher total payment relative to the benchmark. The higher payment compensates for the disutility the seller gets from the spite towards the buyer.

More interestingly, the presence of other preferences can impact the terms of trade in the carbon market. If parties are inequality averse, the discount factor needed for self-enforcement does not change relative to the benchmark case of self-interested parties. However, if either party is altruistic, the buyer and the seller are less likely to engage in opportunistic behavior that would lead to a break down in trade, i.e., cooperation is more likely. This happens because the lowest discount factor that sustains cooperation and long-run trade is negatively related to the altruism parameter. This result is also true for the case in which either party receives a warm-glow from participating in carbon sequestration activities.

In contrast, the presence of a spiteful party increases the chances that the parties will engage in opportunistic behavior and trade will break down compared to the case of purely profit-maximizing parties. When a party feels spite towards the other party, he gets a lower per period utility than if he would not care about the other participant's material gains, therefore he needs a higher discount factor to maintain the value of the discounted stream of benefits higher than the benefits from deviation. As a consequence, cooperation is more difficult to maintain.

Finally, the per period monetary payoffs equal the per period total utility the buyer and the seller get respectively when both parties are self-interested and when either party is inequality averse. This is also true for the buyer when parties get warm-glow from carbon sequestration or when the buyer is self-interested but the seller is altruistic or spiteful. In the case of the seller, her monetary payoffs also equal the per period total utility when the buyer is altruistic or spiteful while the seller gets higher and lower monetary payoff than total utility respectively. In contrast, the seller gets higher monetary payoffs than total utility when he is spiteful and the opposite is true when she is altruistic.

Furthermore, the buyer gets higher monetary payoffs while the seller gets lower monetary payments than the benchmark when the seller is altruistic or holds warm-glow preferences. By the same token, the buyer receives lower monetary payments when the seller is spiteful or either party is averse to inequality while the seller gets a higher monetary payoff than in the benchmark. When the buyer is altruistic or spiteful the monetary payments for each party are the same as the self-interested case. Lastly, only in the presence of inequality aversion preferences, the buyer and the seller share equally the surplus and get the same monetary payoffs and total utility.

The results outlined here show that if parties care about the material payoffs of the other party or care about carbon sequestration per se, they may be more or less willing to cooperate and sustain the relationship over time than when they only care about own monetary payoffs. These results have interesting implications for the design of self-enforcing REDD contracts. When contracts are offered by an organization that has objectives in addition to profit maximization, long-term achievement of climate goals are more likely to occur. The results suggest that cooperation in carbon sequestration may be more sustainable with real world examples of buyers that have a history of concern about stakeholders or observable objectives in line with more altruistic goals. For example, REDD contracts offered by organizations such as Conservation International as well as governments with a history of strong commitments to environmental protection such as Costa Rica could be examples of altruistic buyers that could trigger greater cooperation.

In addition, buyers could express altruism in other ways. For instance, national and local governments that offer better social safety nets or less corrupt governance may also be an example of an altruistic buyer. Such governments could present a great opportunity for engaging in successful carbon sequestration while providing additional economic benefits to REDD participants in their countries.

In contrast, the results also suggest that a more self-interested party including profit maximizing firms such as electric companies or nations with a past history of rent seeking and corruption would be less likely to achieve cooperation in REDD contracts. For example, in countries where lands have been historically used for generating rents directed to the elite groups instead of for broader public needs, greater public ownership or control of forest lands might lead to more spite and less cooperation.

These results open an interesting avenue for additional research as it leads to testable hypotheses and stimulates questions about how different forms of non-self-interested preferences (e.g., maximin preferences or preferences for equality) might impact optimal relational

Table 2: Models

Preferences	Buyer function	Seller function	Individual rational constraint/ Self-enforcing constraint	
			Buyer	Seller
Self-interest	$U_b^m = V(q) - P(q)$	$U_s^m = P(q) - c(q)$	$U_b^m = V(q) - P(q) \geq \bar{\pi}$ $\frac{V_t(q_t) - P_t(q_t)}{1-\delta} \geq V(q) - p + \frac{\delta}{1-\delta} \bar{\pi}$	$U_s^m = P(q) - c(q) \geq \bar{u}$ $\frac{P_t(q_t) - c(q_t)}{1-\delta} \geq p - c(q) + \frac{\bar{u}}{1-\delta}$
Altruism	$U_b^a = V(q) - P(q) + a_b U_s^m$	$U_s^a = P(q) - c(q) + a_s U_b^m$	$U_b^a = V(q) - P(q) + a_b U_s^m \geq \bar{\pi}$ $\frac{V_t(q_t) - P_t(q_t) + a_b \bar{U}_{st}^m}{1-\delta} \geq V(q) - p + a_b \bar{U}_{st}^m + \frac{\delta}{1-\delta} \bar{\pi}$	$U_s^a = V(q) - P(q) + a_s U_b^m \geq \bar{\pi}$ $\frac{P_t(q_t) - c(q_t) + a_s \bar{U}_{bt}^m}{1-\delta} \geq p - c(q) + a_s \bar{U}_{bt}^m + \frac{\bar{u}}{1-\delta}$
Spite	$U_b^s = V(q) - P(q) - a_b U_s^m$	$U_s^s = P(q) - c(q) - a_s U_b^m$	$U_b^s = V(q) - P(q) - a_b U_s^m \geq \bar{\pi}$ $\frac{V_t(q_t) - P_t(q_t) - a_b \bar{U}_{st}^m}{1-\delta} \geq V(q) - p - a_b \bar{U}_{st}^m + \frac{\delta}{1-\delta} \bar{\pi}$	$U_s^s = V(q) - P(q) - a_s U_b^m \geq \bar{\pi}$ $\frac{P_t(q_t) - c(q_t) - a_s \bar{U}_{bt}^m}{1-\delta} \geq p - c(q) - a_s \bar{U}_{bt}^m + \frac{\bar{u}}{1-\delta}$
Inequality Aversion	$U_b^{IA}(x_s, x_b) = V(q) - P(q)$ $-\alpha_b \max\{x_s - x_b, 0\}$ $-\beta_b \max\{x_b - x_s, 0\}$	$U_s^{IA}(x_s, x_b) = P(q) - c(q)$ $-\alpha_s \max\{x_b - x_s, 0\}$ $-\beta_s \max\{x_s - x_b, 0\}$	$U_b^m = V(q) - P(q) \geq \bar{\pi}$	$U_s^m = V(q) - P(q) \geq \bar{\pi}$ $\frac{P_t(q_t) - c(q_t)}{1-\delta} \geq p - c(q) + \frac{\bar{u}}{1-\delta}$
Warm-Glow	$U_b^{WG} = V(q) - P(q) + g_b q$	$U_s^{WG} = P(q) - c(q) + g_s q$	$U_b^{WG} = V(q) - P(q) + g_b q \geq \bar{\pi}$	$U_s^{WG} = P(q) - c(q) + g_s q \geq \bar{u}$ $\frac{V_t(q_t) - P_t(q_t) + g_b q_t}{1-\delta} \geq V(q) - p + g_b q + \frac{\bar{u}}{1-\delta}$

contracts. However, the models in this paper assumed that each party has perfect knowledge of the other party's preference type, ignoring any issues that may arise with the existence of hidden information. For the empirical implementation of carbon sequestration contracts participants' ability of distinguishing preference types may be crucial for long-term success. Carbon sellers may be able to observe buyers' objectives more easily and distinguish buyer type. For example, it would be easy to distinguish the pure profit-maximizing type of an electrical company in contrast with more altruistic objectives of the United Nations Collaborative Program on Reducing Emissions from Deforestation and Forest Degradation in Developing Countries. Yet individual sellers' preferences would more difficult to identify. The difficulties derived from the inability to distinguish preference type are something to consider for future research and the implementation of carbon sequestration contracts.

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Appendix A: Proofs

Proof of Proposition 1. First let's prove that IRC_s^m binds. If IRC_s^m binds, then $P(q) - c(q) = \bar{u}$. Substituting IRC_s^m in $DICC_s^m$ yields: $\frac{\bar{u}}{1-\delta} \geq \frac{\bar{u}}{1-\delta}$, which is true. Then IRC_s^m binds. If $DICC_s^m$ binds we have $\frac{p+b(q)-c(q)}{1-\delta} = p - c(\underline{q}) + \frac{\bar{u}}{1-\delta}$. Rearranging we get $b(q) = c(q) - \delta p + \bar{u}$ and by substituting in IRC_s^m we get $p > 0$ which is not true as by assumption the fixed payment can be zero. Now let y^* be the equilibrium contract that a buyer offers to a seller, where $P(Q) = p + b(Q)$. The buyer maximizes profits holding IRC_s^m with equality: $P(q) = \bar{u} + c(q)$, and solving for p in both IRC_s^m ($p = \bar{u} + c(q) - b(q)$) and $DICC_s^m$ ($p \geq c(\underline{q}) + \frac{c(q) - c(\underline{q}) + \bar{u} - b(q)}{\delta}$). Substituting IRC_s^m on $DICC_s^m$ and rearranging we get $b(q) \geq c(q) - c(\underline{q}) + \bar{u}$, which holds with equality because the buyer is maximizing his utility subject to the participation of the seller. He will only offer a $b(q)$ large enough to induce quality and participation. Substituting back into the IRC_s^m and rearranging leads to $p \leq c(\underline{q})$, which is zero because by assumption $c(\underline{q}) = 0$. Combining p and $b(q)$ the total payment is $P(q) = \bar{u} + c(q)$. Substituting $P(q)$ in the buyer's objective function, solving for the first order Kuhn-Tucker conditions:

$$V'(q) \begin{cases} < c'(q) & \text{if } q^* = \underline{q} \\ = c'(q) & \text{if } \underline{q} < q^* < \bar{q} \\ > c'(q) & \text{if } q^* = \bar{q}. \end{cases}$$

Since $V'(q) > c'(q) \quad \forall q \in [\underline{q}, \bar{q}]$ and $q \neq \underline{q}$ by assumption, then the buyer requests $q^* = \bar{q}$. Therefore, $P(\bar{q}) = p + b(\bar{q}) = c(\bar{q}) + \bar{u}$. Let's check the participation constraint of the buyer. Substituting $P(q)$ we get: $V(\bar{q}) - c(\bar{q}) - \bar{u} \geq \bar{\pi}$, which ends up being $S(\bar{q}) - \bar{s} \geq 0$, which is true since $q = \bar{q}$ and, by assumption, $S(\bar{q}) - \bar{s} \geq 0 \quad \forall q \in [\underline{q}, \bar{q}]$ and $q \geq \underline{q}$. For cooperation to be achievable, the DICC of both parties must hold. Then, combining equations $DICC_s^m$ and $DICC_b^a$ we get: $\underline{\delta}^m \geq \frac{c(q) - c(\underline{q}) + \bar{u}}{V(q) - c(\underline{q}) - \bar{\pi}}$. Recalling that $c(\underline{q}) = 0$, $\underline{\delta}^m \geq \frac{c(q) + \bar{u}}{V(q) - \bar{\pi}}$. Hence, cooperation takes place for all values of delta that satisfy $\underline{\delta}^m$. $\square$

Proof of Proposition 3. First let's prove that IRC_s^m binds. If IRC_s^m binds, then $P(q) - c(q) = \bar{u}$. Substituting IRC_s^m in $DICC_s^m$ yields: $\frac{\bar{u}}{1-\delta} \geq \frac{\bar{u}}{1-\delta}$, which is true. Then IRC_s^m binds. If $DICC_s^m$ binds we have $\frac{p+b(q)-c(q)}{1-\delta} = p - c(\underline{q}) + \frac{\bar{u}}{1-\delta}$. Rearranging we get $b(q) = c(q) - \delta p + \bar{u}$ and by substituting in IRC_s^m we get $p > 0$ which is not true as by assumption the fixed payment can be zero. Now let y^* be the equilibrium contract that a buyer offers to an agent, where $P(Q) = p + b(Q)$. The buyer maximizes profits holding IRC_s^m with equality: $P(q) = \bar{u} + c(q)$, and solving for p in both IRC_s^m ($p = \bar{u} + c(q) - b(q)$) and $DICC_s^m$ ($p \geq c(\underline{q}) + \frac{c(q) - c(\underline{q}) + \bar{u} - b(q)}{\delta}$). Substituting IRC_s^m on $DICC_s^m$ and rearranging we get $b(q) \geq c(q) - c(\underline{q}) + \bar{u}$, which holds with equality because the buyer is maximizing his utility subject to the participation of the seller. He will only offer a $b(q)$ large enough to induce quality and participation. Substituting back into the IRC_s^m and rearranging leads to $p \leq c(\underline{q})$. Combining p and $b(q)$ the total payment is $P(q) = \bar{u} + c(q)$. Substituting $P(q)$ in the buyer's objective function, solving for the first order Kuhn-Tucker conditions and since

$$V'(q) \begin{cases} < c'(q) & \text{if } q^* = \underline{q} \\ = c'(q) & \text{if } \underline{q} < q^* < \bar{q} \\ > c'(q) & \text{if } q^* = \bar{q}. \end{cases}$$

$V'(q) > c'(q) \quad \forall q \in [\underline{q}, \bar{q}]$ and $q \neq \underline{q}$ by assumption, then the principal requests $q^* = \bar{q}$. Therefore, $P(\bar{q}) = p + b(\bar{q}) = c(\bar{q}) + \bar{u}$. Finally, checking the buyer's DICC it is satisfied for $a_b \geq \frac{c(q) + \bar{u} + \delta\bar{\pi} - \delta V(q)}{(1-\delta)c(q) + \bar{u}} \in (0, 1)$, given $S(q) > \bar{s}$. Let's check the participation constraint of the buyer. Substituting $P(q)$ we get: $V(\bar{q}) - c(\bar{q}) - \bar{u} + a_b(c(q) + \bar{u} - c(q)) \geq \bar{\pi}$, which ends up being $S(\bar{q}) - \bar{s} + a_b\bar{u} \geq 0$, which is true since $q = \bar{q}$ and, by assumption, $S(\bar{q}) - \bar{s} \geq 0 \quad \forall q \in [\underline{q}, \bar{q}]$ and $q \geq \underline{q}$ and $a_b\bar{u} \geq 0$. For cooperation to be achievable, the DICC of both parties must hold. Then, combining equations $DICC_s^s$ and $DICC_b^a$ we get: $\underline{\delta}^{a^b} \geq \frac{(c(q) - c(\underline{q}) + \bar{u})(1 - a_b)}{V(q) - c(\underline{q}) - \bar{\pi} - a_b(c(q) - c(\underline{q}))}$. Recalling $c(\underline{q}) = 0$, $\underline{\delta}^{a^b}$ can be rewritten as $\underline{\delta}^{a^b} = \frac{(c(q) + \bar{u})(1 - a_b)}{V(q) - \bar{\pi} - a_b c(q)}$. Hence, cooperation takes place for all values of delta that satisfy $\underline{\delta}^a$. $\square$

Proof of Proposition 6. First let's prove that IRC_s^a binds. If IRC_s^a binds, then $P(q) - c(q) + a_s U_{bt}^m = \bar{u}$. Substituting IRC_s^a in $DICC_s^a$ yields: $\frac{\bar{u}}{1-\delta} \geq \frac{\bar{u}}{1-\delta}$, which is true. Then IRC_s^a binds. If $DICC_s^a$ binds we have $\frac{p+b(q)-c(q)+a_s \bar{U}_{bt}^m}{1-\delta} = p - c(\underline{q}) + a_s \underline{U}_{bt}^m + \frac{\bar{u}}{1-\delta}$. Rearranging we get $b(q) = c(q) - a_s \bar{U}_b - \delta p + a_s(1-\delta)\underline{U}_b + \bar{u}$ and by substituting in IRC_s^a we get $p > 0$ which is not true as by assumption the fixed payment can be zero. Now let y^* be the equilibrium contract that a buyer offers to a seller, where $P(Q) = p + b(Q)$. The buyer maximizes profits holding IRC_s^a with equality: $P(q) = \bar{u} + c(q)$, and solving for p in both IRC_s^a ($p = \bar{u} + c(q) - b(q) - a_s U_{bt}^m$) and $DICC_s^a$ ($p \geq \frac{c(q) + \bar{u} - (1-a_s)b(q) - a_s V(q) + (1-\delta)(a_s V(\underline{q}) - c(\underline{q}))}{\delta(1-a_s)}$). Substituting IRC_s^a on $DICC_s^a$ and rearranging we get $b(q) = \frac{c(q) - c(\underline{q}) + \bar{u} - a_s(V(q) - V(\underline{q}))}{1-a_s}$, which holds with equality because the buyer is maximizing his utility subject to the participation of the seller. He will only offer a $b(q)$ large enough to induce quality and participation. Substituting back into the IRC_s^a and rearranging leads to $p \leq \frac{c(\underline{q}) - a_s V(\underline{q})}{1-a_s}$, which is zero because by assumption $c(\underline{q}) = 0$ and $V(\underline{q}) = 0$. Combining p and $b(q)$ the total payment is $P(q) = \frac{\bar{u} + c(q) - a_s V(q)}{1-a_s}$. Substituting $P(q)$ in the buyer's objective function, solving for the first order Kuhn-Tucker conditions:

$$V'(q) \begin{cases} < c'(q) & \text{if } q^* = \underline{q} \\ = c'(q) & \text{if } \underline{q} < q^* < \bar{q} \\ > c'(q) & \text{if } q^* = \bar{q}. \end{cases}$$

Since $V'(q) > c'(q) \ \forall q \in [\underline{q}, \bar{q}]$ and $q \neq \underline{q}$ by assumption, then the buyer requests $q^* = \bar{q}$. Therefore, $P(\bar{q}) = p + b(\bar{q}) = \frac{\bar{u} + c(\bar{q}) - a_s V(\bar{q})}{1-a_s}$. Let's check the participation constraint of the buyer. Substituting $P(q)$ we get: $V(\bar{q}) - \frac{\bar{u} + c(\bar{q}) - a_s V(\bar{q})}{1-a_s} \geq \bar{\pi}$, which ends up being $\frac{S(\bar{q}) - \bar{u}}{1-a_s} \geq \bar{\pi}$, which is true for any $a_b \geq 0$ since $q = \bar{q}$ and, by assumption, $S(\bar{q}) - \bar{s} \geq 0 \ \forall q \in [\underline{q}, \bar{q}]$ and $q \geq \underline{q}$. For cooperation to be achievable, the DICC of both parties must hold. Then, combining equations $DICC_s^a$ and $DICC_b^m$ we get: $\underline{\delta}^{a^s} \geq \frac{c(q) - c(\underline{q}) + \bar{u} - a_s(V(q) - V(\underline{q}))}{V(q) - c(\underline{q}) - \bar{\pi} - a_s(V(q) - V(\underline{q}) - \bar{\pi})}$. Recalling the assumption of $c(\underline{q}) = 0$ and $V(\underline{q}) = 0$, $\underline{\delta}^{a^s}$ reduces to $\underline{\delta}^{a^s} \geq \frac{c(q) + \bar{u} - a_s V(q)}{(1-a_s)(V(q) - \bar{\pi})}$. Hence, cooperation

takes place for all values of delta that satisfy $\underline{\delta}^{a^s}$.

□

Proof of Proposition 8. First let's prove that IRC_s^s binds. If IRC_s^s binds, then $P(q) - c(q) - a_s U_{bt}^m = \bar{u}$. Substituting IRC_s^s in $DICC_s^s$ yields: $\frac{\bar{u}}{1-\delta} \geq \frac{\bar{u}}{1-\delta}$, which is true. Then IRC_s^s binds. If $DICC_s^s$ binds we have $\frac{p+b(q)-c(q)-a_s \bar{U}_{bt}^m}{1-\delta} = p - c(q) - a_s U_{bt}^m + \frac{\bar{u}}{1-\delta}$. Rearranging we get $b(q) = c(q) + a_s \bar{U}_b - \delta p - a_s(1-\delta)U_b + \bar{u}$ and by substituting in IRC_s^s we get $p > 0$ which is not true as by assumption the fixed payment can be zero. Now let y^* be the equilibrium contract that a buyer offers to a seller, where $P(Q) = p + b(Q)$. The buyer maximizes profits holding IRC_s^s with equality: $P(q) = \bar{u} + c(q) + a_s U_{bt}^m$, and solving for p in both IRC_s^s ($p = \bar{u} + c(q) - b(q) + a_s U_{bt}^m$) and $DICC_s^a$ ($p \geq \frac{c(q) + \bar{u} - (1+a_s)b(q) + a_s V(q) + (1-\delta)(a_s V(q) - c(q))}{\delta(1+a_s)}$). Substituting IRC_s^s on $DICC_s^s$ and rearranging we get $b(q) = \frac{c(q) - c(\underline{q}) + \bar{u} + a_a(V(q) - V(\underline{q}))}{1+a_a}$, which holds with equality because the buyer is maximizing his utility subject to the participation of the seller. He will only offer a $b(q)$ large enough to induce quality and participation. Substituting back into the IRC_s^s and rearranging leads to $p \leq \frac{c(\underline{q}) + a_a V(\underline{q})}{1+a_a}$, which is zero because by assumption $c(\underline{q}) = 0$ and $v(\underline{q})$. Combining p and $b(q)$ the total payment is $P(q) = \frac{\bar{u} + c(q) + a_a V(q)}{1+a_a}$. Substituting $P(q)$ in the buyer's objective function, solving for the first order Kuhn-Tucker conditions:

$$V'(q) \begin{cases} < c'(q) & \text{if } q^* = \underline{q} \\ = c'(q) & \text{if } \underline{q} < q^* < \bar{q} \\ > c'(q) & \text{if } q^* = \bar{q}. \end{cases}$$

Since $V'(q) > c'(q) \quad \forall q \in [\underline{q}, \bar{q}]$ and $q \neq \underline{q}$ by assumption, then the buyer requests $q^* = \bar{q}$. Therefore, $P(\bar{q}) = p + b(\bar{q}) = \frac{\bar{u} + c(\bar{q}) + a_s V(\bar{q})}{1+a_s}$. Let's check the participation constraint of the buyer. Substituting $P(q)$ we get: $V(\bar{q}) - \frac{\bar{u} + c(\bar{q}) + a_s V(\bar{q})}{1+a_s} \geq \bar{\pi}$, which ends up being $S(\bar{q}) - \bar{s} \geq a_s \bar{\pi}$, which is true as long as $a_b \leq \frac{S(\bar{q}) - \bar{s}}{\pi}$ for $q = \bar{q}$ and, by assumption, $S(\bar{q}) - \bar{s} \geq 0 \quad \forall q \in [\underline{q}, \bar{q}]$

and $q \geq \underline{q}$. For cooperation to be achievable, the DICC of both parties must hold. Then, combining equations $DICC_s^s$ and $DICC_b^m$ we get: $\underline{\delta}^{ss} = \frac{c(q) - c(\underline{q}) + \bar{u} + a_a(V(q) - V(\underline{q}))}{V(q) - c(\underline{q}) - \bar{\pi} + a_a(V(q) - V(\underline{q}) - \bar{\pi})}$. Recalling again $c(\underline{q}) = 0$ and $V(\underline{q}) = 0$, $\underline{\delta}^{ss}$ can be rewritten as $\underline{\delta}^{ss} = \frac{c(q) + \bar{u} + a_s V(q)}{(1 + a_s)(V(q) - \bar{\pi})}$. Hence, cooperation takes place for all values of delta that satisfy $\underline{\delta}^{ss}$.

□

Proof of Proposition 9. To maximize the fair-type's objective function $P_t(q_t) = \frac{V(q) + c(q)}{2}$. Substituting in the IRC_s^s , the following inequality must be true for a seller to accept the contract: $V(q) - c(q) \geq 2\bar{u}$. Let y^* be the equilibrium contract that a buyer offers to a seller, where $P_t(q_t) = \frac{V(q) + c(q)}{2}$. Solving for p , $p = \frac{V(q) + c(q)}{2} - b(q)$. Also, solving for p in the $DICC_s^m$ ($p \geq c(\underline{q}) + \frac{c(q) - c(\underline{q}) + \bar{u} - b(q)}{\delta}$) and substituting p on $DICC_s^m$ and rearranging we get $b(q) = \frac{c(q) + \bar{u}}{1 - \delta} - \frac{\delta(V(q) + c(q))}{2(1 - \delta)} - c(\underline{q})$, which holds with equality because the buyer is maximizing his utility given his preferences. Substituting into the IRC_s^m and rearranging leads to $p = \frac{V(q) - c(q) - 2\bar{u}}{2(1 - \delta)} + c(\underline{q})$, which is $p = \frac{V(q) - c(q) - 2\bar{u}}{2(1 - \delta)}$ because by assumption $c(\underline{q}) = 0$. Combining p and $b(q)$ the total payment is $P(q) = \frac{V(q) + c(q)}{2}$. Substituting $P(q)$ in the buyer's objective function, solving for the first order Kuhn-Tucker conditions:

$$V'(q) \begin{cases} < c'(q) & \text{if } q^* = \underline{q} \\ = c'(q) & \text{if } \underline{q} < q^* < \bar{q} \\ > c'(q) & \text{if } q^* = \bar{q}. \end{cases}$$

Since $V'(q) > c'(q) \quad \forall q \in [\underline{q}, \bar{q}]$ and $q \neq \underline{q}$ by assumption, then the buyer requests $q^* = \bar{q}$. Therefore, $P(\bar{q}) = p + b(\bar{q}) = \frac{V(\bar{q}) + c(\bar{q})}{2}$. Let's check the participation constraint of the buyer. Substituting $P(q)$ we get: $V(\bar{q}) - \frac{V(\bar{q}) + c(\bar{q})}{2} \geq \bar{\pi}$, which holds if $\frac{S(\bar{q})}{2} \geq \bar{\pi}$. For cooperation to be achievable, the DICC of both parties must hold. Then, combining equations $DICC_s^m$ and $DICC_b^m$ we get: $\underline{\delta}^{IA} = \frac{c(q) - c(\underline{q}) + \bar{u}}{V(q) - c(\underline{q}) - \bar{\pi}}$. Recalling again the assumption that $c(\underline{q}) = 0$, the parameter $\underline{\delta}^{IA}$ can be rewritten as $\underline{\delta}^{IA} = \frac{c(q) + \bar{u}}{V(q) - \bar{\pi}}$. Hence, cooperation takes place for all values

of delta that satisfy $\underline{\delta}^{IA}$.

□

Proof of Proposition 11. The buyer maximizes profits holding $IRC^W G_s$ with equality: $P_t(q_t) - c(q) + g_s q = \bar{u}$, and solving for p in both $IRC^W G_s$ ($p = c(q) - g_s q + \bar{u} - b(q)$) and $DICC^W G_s$ ($p \geq \frac{c(q_t) - g_s q_t - c(\underline{q}) + g_s \underline{q} + \bar{u} - b(\underline{q})}{\delta} + c(\underline{q}) - g_s \underline{q}$). Substituting $IRC^W G_s$ on $DICC^W G_s$ and rearranging we get $b(q) = c(q) - c(\underline{q}) - g_s(q - \underline{q}) + \bar{u}$, which holds with equality because the buyer is maximizing his utility subject to the participation of the seller. He will only offer a $b(q)$ large enough to induce quality and participation. Substituting back into the $IRC^W G_s$ and rearranging leads to $p = c(\underline{q}) - g_s \underline{q}$, which is zero because by assumption $c(\underline{q}) = 0$ and $g_s \underline{q} = 0$. Combining p and $b(q)$ the total payment is $P(q) = c(q) + \bar{u} - g_s q$. Substituting $P(q)$ in the buyer's objective function, solving for the first order Kuhn-Tucker conditions:

$$V'(q) + g_s \begin{cases} < c'(q) & \text{if } q^* = \underline{q} \\ = c'(q) & \text{if } \underline{q} < q^* < \bar{q} \\ > c'(q) & \text{if } q^* = \bar{q}. \end{cases}$$

Since $V'(q) > c'(q) \quad \forall q \in [\underline{q}, \bar{q}]$ and $q \neq \underline{q}$ by assumption, then the buyer requests $q^* = \bar{q}$.

Therefore, $P(\bar{q}) = p + b(\bar{q}) = P(q) = c(\bar{q}) + \bar{u} - g_s \bar{q}$.

Let's check the participation constraint of the buyer. Substituting $P(q)$ we get: $V(\bar{q}) - c(q) - \bar{u} + g_s \bar{q} \geq \bar{\pi}$, which ends up being $S(\bar{q}) - \bar{s} + g_s \bar{q} \geq 0$, which is true as by assumption, $S(\bar{q}) - \bar{s} \geq 0 \quad \forall q \in [\underline{q}, \bar{q}]$ and $q \geq \underline{q}$. For cooperation to be achievable, the DICC of both parties must hold. Then, combining equations $DICC^W G_s$ and $DICC^W G_b$ we get: $\underline{\delta}^{WG} = \frac{c(q) - c(\underline{q}) + \bar{u} - g_s(q - \underline{q})}{V(q) - c(\underline{q}) - \bar{\pi} + g_b q + g_s \underline{q}}$. Recalling again the assumption that $c(\underline{q}) = 0$, the parameter $\underline{\delta}^{IA}$ can be rewritten as $\underline{\delta}^{WG} = \frac{c(q) + \bar{u} - g_s(q - \underline{q})}{V(q) - \bar{\pi} + g_b q + g_s \underline{q}}$. Hence, cooperation takes place for all values of delta that satisfy $\underline{\delta}^{WG}$.

□

Appendix B: Numerical Example

Suppose that a buyer wants to contract with a forest-owner that owns exploitation rights over 100 hectares of forested-land. Each hectare of forest is equivalent to 81 tonnes of biomass carbon stocks sequestered above and below ground. The forest-owner can maintain the forest which costs him \$5 per hectare, or she can receive a net profit of \$30 per hectare by harvesting and selling timber. The per period price for carbon offsets is \$3 per tonne of carbon sequestered and assume that the buyer's outside option equals zero. Following the set up of the model in Essay Three, the next relationships can be established.

$$(A-1) \quad V(q_t) = 3 * 8100 = 24300$$

$$(A-2) \quad c(q_t) = 5 * 100 = 500$$

$$(A-3) \quad \bar{u} = 30 * 100 = 3000$$

$$(A-4) \quad \bar{\pi} = 0$$

$$(A-5) \quad V(q_t) - c(q_t) = 23800$$

Finally, assume that both parties may be altruistic or spiteful with $a_b = a_s = 0.1$ or may have warm=glow concerns with $g_b = g_s = 0.1$. Table 1 presents the results for each model.

Table 3: Summary results

B-S Func- tion	Payment	Discount factor	Monetary payoffs (per period)	Total Utility (per period)
U_b^m, U_s^m	$P(q) = 3500$ $p = 0$ $b(q) = 3500$	$\delta \geq \underline{\delta}^m = 0.1440$	$U_b^m = 20800$ $U_s^m = 3000$	$U_b^m = 20800$ $U_s^m = 3000$
U_b^a, U_s^m	$P(q) = 3500$ $p = 0$ $b(q) = 3500$	$\underline{\delta}^m > \underline{\delta}^{a^b} = 0.1298$	$U_b^a = 20800$ $U_s^m = 3000$	$U_b^a = 21100$ $U_s^m = 3000$
U_b^s, U_s^m	$P(q) = 3500$ $p = 0$ $b(q) = 3500$	$\underline{\delta}^m < \underline{\delta}^{s^b} = 0.1581$	$U_b^s = 20800$ $U_s^m = 3000$	$U_b^s = 20500$ $U_s^m = 3000$
U_b^m, U_s^a	$P(q) = 1189$ $p = 0$ $b(q) = 1189$	$\underline{\delta}^m > \underline{\delta}^{a^s} = 0.0489$	$U_b^m = 23111$ $U_s^a = 689$	$U_b^m = 23111$ $U_s^a = 3000$
U_b^m, U_s^s	$P(q) = 5391$ $p = 0$ $b(q) = 5391$	$\underline{\delta}^m < \underline{\delta}^{s^s} = 0.2218$	$U_b^m = 18909$ $U_s^s = 4891$	$U_b^m = 18909$ $U_s^s = 3000$
U_b^{IA}, U_s^{IA}	$P(q) = 12400$ $p = 10397.20$ $b(q) = 2002.80$	$\underline{\delta}^m = \underline{\delta}^{IA} = 0.1440$	$U_b^{IA} = 11900$ $U_s^{IA} = 11900$	$U_b^{IA} = 11900$ $U_s^{IA} = 11900$
U_b^{WG}, U_s^{WG}	$P(q) = 2690$ $p = 0$ $b(q) = 2690$	$\underline{\delta}^m > \delta^{WG} = 0.1071$	$U_b^{WG} = 21610$ $U_s^{WG} = 2190$	$U_b^{WG} = 22420$ $U_s^{WG} = 3000$