The Conservation Contradiction and Political Remedies*

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Abstract

This paper discusses a fundamental market failure regarding environmental conservation, and how the problem can be solved by appropriate policies. A "seller" (or owner of a tropical forest) may be motivated to conserve if a "buyer" is expected to pay. The buyer, however, does not find it necessary to pay as long as the seller conserves in any case. This contradiction implies that the forest will gradually decline and the seller has no incentive to enhance the environmental value. However, the forest can be conserved today if sufficient future funds are credibly pledged, even if these are delayed and uncertain.

Key words: Conservation, deforestation, dynamic games, time inconsistency.

JEL: D78, D62, H87, Q30, Q23.

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1 Introduction

Tropical deforestation has amounted to about one quarter of accumulated anthropogenic greenhouse gas emissions (Edenhofer et al., 2014), and its annual contribution to CO2 emissions is 10-15 percent (Stocker et al., 2013) and even more for other greenhouse gases. In addition, deforestation leads to the loss of biodiversity and of indigenous tribes' homes. The negative externalities of deforestation may amount to \$2-4.5 trillion a year (*The Economist*, 2010). In addition, it is clear that deforestation could be prevented at a modest cost. Edenhofer at al. (2014) argue that deforestation could be halved at a cost of \$21-35 billion per year, while Busch et al. (2012) show that it can be reduced by 20-30 percent at a price of \$10/tCO2.3. Clearly, the world's benefit from conservation far outweighs the costs to the owner. Based on Coase (1960), one would thus think that the North would simply pay the tropical countries in the South to conserve and protect their forests. Perhaps surprisingly, this happens to only a very limited extent through the UN program REDD ("Reducing Emissions from Deforestation and Forest Degradation"). Thus, deforestation has been increasing at a rate of 2101 km2/year since 2000 (Hansen et al., 2013; Harris et al., 2012).

This article discusses a fundamental contradiction regarding paying for conservation, and analyzes policies that may work. At the core of the problem lies the role of expectations: An owner of a tropical forests in the South is motivated to protect and conserve if the North is expected to pay and compensate for this effort later on. The North, however, does not find it necessary to pay as long as the South is conserving in any case. This contradiction implies that in the game between the South and the North, there is no equilibrium in which the forest is fully conserved. Instead, the forest must be logged with some positive probability (to motivate the North to pay) or it must be cut gradually at a relatively fast rate.

This paper offers a number of new results. The expected fraction of the forest that will remain forever is, paradoxically, smaller if the environmental value of conservation is large. The reason is that when the environmental value is large, the owner can ask for a steep price when conserving the forest. The steep price implies that the North can pay with a smaller probability without inducing the South to end conservation. Thus, it is quite likely that the

South ends conservation before the North has paid if the environmental value is large.

The roles of incentives and investments are also surprisingly distorted. In fact, even if the South could enhance the forest's environmental value, it would have no incentive to do so. Even if such an investment raised the price that the South could expect from conserving the forest, the higher price would be accompanied by a smaller probability that the North would actually pay. The North may benefit from boycotting and thereby reducing the South's profits from logging, but such a boycott would reduce aggregate welfare because the North would buy on a smaller scale when the South is less tempted to log. A better policy option is to try to strengthen the buyer's bargaining power. This would reduce the equilibrium price, reduce the probability of cutting, raise the probability of conservation and the buyer's payoff. At the same time, the seller's payoff would remain the same, since the larger probability that the buyer pays compensates the seller for the lower price it will then receive. After all, the conservation contradiction studied in this paper does not arise because the seller is unwilling to conserve at the equilibrium price, but because the buyer is unwilling to pay if the seller is in any case tempted to conserve.

If there are many countries potentially interested in conservation, the problem only worsens. In this situation, each buyer prefers to wait and hopes that one of the other countries will instead pay for conservation. To nevertheless motivate countries to pay, deforestation must occur at a faster rate when there are many potential buyers. Two solutions are discussed below: the buyers can either coordinate, in that they single out one particular buyer to deal with the seller, or they can cooperate, by acting as one single buyer (who, then, naturally will have a higher willingness to pay of conservation). It is shown below that the buyers are equally much better off if they cooperate on paying for conservation than they would be if they just coordinate by sorting out which country should be the one that negotiates and pays.

Despite the fundamental market inefficiency, the solution to the conservation contradiction is found close to the source of the problem: in the expectations. If the North could merely credibly commit to pay for conservation in the future, the South would be motivated to monitor and protect the forest already today. Thus, conservation can take place today even though payments are not immediate; it is sufficient to make a credible plan that such compensations will be offered in the future. Note that the positive immediate effect of future policies is the opposite of the negative effect discussed in the literature on "the green paradox" (Sinn, 2008; 2012. See also Kremer and Morcom, 2000). The reason for the reversal in results is that it is here assumed that the seller is compensated rather than expropriated.

Naturally, the fund necessary to motivate conservation must increase if the date at which it will be granted is further delayed into the future, or if the probability at which it will be offered is reduced.

To make future compensations credible, it may be necessary for the various countries to sign multi-lateral agreements that "tie their hands," at some level. By using each other as third party enforcers, the fact that there are multiple buyers interested in conservation can be turned into an asset rather than being a problem. A policy conclusion is thus that if a global climate agreement can establish funds that ought to be used in the future to compensate for conservation, the positive effect would be materialized immediately. So far, however, climate agreements have committed to funds mainly as a way to finance technology transfers and help regarding adaptation (FCCC, 2016).

To explain tropical deforestation, many scholars point to corruption, unclear property rights, re-electoral concerns, and collective action problems. (For a literature review, see Alston and Andersson, 2011; or Angelsen, 2010. For empirical studies, see Burgess et al. (2011), or Damette and Delacote (2012).) In contrast to these contributions, the present article focuses on why the North fails to pay the required amount to the South. This inefficiency is related to the problem of sales in the presence of externalities (Jehiel and Moldovanu 1995), since the forest owner's sale to a logger creates negative externalities on those countries that benefit from conservation. Other related papers are by Dixit and Olson (2000) and Ellingsen and Paltseva (2016), who show that there may be insufficient public good provision if agents have the choice to free-ride. In this paper, in contrast, the good in question does not need to be provided; it only needs to be conserved.

The relationship to the theoretical literature is more thoroughly explained in my companion paper (Harstad, 2016), which also discusses the inefficiency in the market for conservation and the fact that the equilibrium must be in mixed strategies. That paper is technically more sophisticated in that prices are functions of continuation values, and in the way leasing agreements are compared to sales, for example. Furthermore, that paper also discussed the role of renegotiation. However, the model presented below is different and novel in several respects, and I also offer a number of new results here. In terms of the model, I below provide both a (new) static model of the conservation contradiction, before I introduce the continuous-time framework. I also find it pedagogical to let the price be given by the Nash bargaining solution, leading to several intuitive results. In terms of results, the present paper (in contrast to Harstad, 2016), studies purification and gradual deforestation, the fraction of the forest that will be conserved forever, and, crucially, the seller's incentives to invest in conservation. Nevertheless, the most important contribution of the present paper lays in the discussion of policies, such as coordination and cooperation, and especially how establishing funds to compensate for conservation will help.

The next section presents a static model before a dynamic model is analyzed. Thereafter, I discuss gradual deforestation, the fate of the forest, the incentives to invest and the effects of boycotting the forest products. The second half of the paper focuses on multiple buyers and policy remedies such as coordination, cooperation, and funds that are set up in advance to compensate for fututre conservation. Section 5 concludes, and the Appendix contains all the proofs.

2 A Static Conservation Game

For a start, suppose there is a single owner or seller (S or "she"), a single buyer (B or "he"), and a single indivisible forest initially owned by the seller. The seller can be interpreted as the South, or as a country possessing tropical forests, while the buyer can be interpreted as the North, the World Bank, or as a country interested in paying for conservation, such as Norway. The seller can always earn $C > 0$ by cutting the forest. The value C may be interpreted either as the value of the logged timber, the present-discounted value of the agricultural products that can be grown on the land, or the present-discounted cost of monitoring and protecting the forest forever; these costs are saved when conservation ends.[1]

[1] Busch et al. (2015: 1328) finds that: "Deforestation in Indonesia is largely driven by the expansion of profitable and legally sanctioned oil palm and timber plantations and logging operations."

Once conservation ends, the buyer B loses the existence value or the environmental value of the forest, denoted $E > 0$. It is assumed that $E > C$, so that both players benefit if S conserves while B pays to S some compensation or price $P \in [C, E]$. The price P can be exogeneous as far as this paper is concerned. However, a simple way of endogenizing P is to let the bargaining outcome be characterized by the generalized (or "asymmetric") Nash bargaining solution where $\alpha \in [0, 1]$ is S's relative bargaining power, while $1 - \alpha$ is B's relative bargaining power. If the threat point is that S cuts, the equilibrium price is:

$$P = (1 - \alpha) C + \alpha E \in [C, E] . \tag{1}$$

If the equilibrium price comes instead from another process, one can let the price be parameterized by α as in (1). Quite generally, α measures how close the price is to the buyer's maximal willingness to pay rather than to the seller's minimal requirement. In any case, we have the equivalence:

$$\alpha \in (0, 1) \Leftrightarrow P \in (C, E) .$$

If instead $E < C$, there would be no price such that conservation could benefit both players.

The players make their decisions simultaneously. In a one-shot setting, the strategic environment and the players' payoffs can be illustrated by a simple 2x2 normal-form game:

S \ B	not buy:	buy:
conserve:	$(0, 0)$	$(P, -P)$
cut:	$(C, -E)$	$(\rho C + (1 - \rho) P, -\rho E - (1 + \rho) P)$

Payoffs: In this normal-form game, the first entry in the parentheses is the seller's payoff, while the second entry is the buyer's payoff.

Both payoffs are normalized to zero if no player acts. Relative to this, S earns C and B loses E if S cuts. If B buys, S earns P and B pays P. If both player acts, one may assume that the seller is "quickest" and cuts before the buyer has bought with some probability $\rho \in [0, 1]$. This explains the payoffs in the bottom-right entry of the table, where the first number denotes the seller's payoff while the second denotes the buyer's payoff.

In this normal-form game, it is simple to see that there is no equilibrium in pure strategies when $P \in (C, E)$ and $\rho \in (0, 1)$. To prove this by contradiction, suppose, for example, that

S is expected to cut. Then, B prefers to buy; but when B is expected to pay, S prefers to conserve. This contradicts the initial claim that S is expected to cut. The only equilibrium is in mixed strategies, implying that with some positive probability, B will not pay and S will cut.

PROPOSITION 1. *In the static conservation game, there is a unique stationary equilibrium, and it is in mixed strategies:*

$$\begin{aligned} b &= \tfrac{C}{\rho P+(1-\rho)C} & \textit{and} \quad c &= \tfrac{P}{(1-\rho)E-\rho P} \\ &= \tfrac{C}{\rho\alpha E+(1-\rho\alpha)C} & &= \tfrac{(1-\alpha)C+\alpha E}{(1-(1+\alpha)\rho)E-\rho(1-\alpha)C}. \end{aligned}$$

The comparative static is interesting. If C is large, S is more tempted to cut, and B must and will buy with a larger probability, in equilibrium. We thus have the paradoxical result that a forest that has a large commercial value is more likely to be purchased for conservation. If E is large, B is more eager to buy, and S can and will cut with a smaller probability in equilibrium. When the price P is endogenous and given by (1), then b is also larger when ρ, α, or E is large. In either of these cases, the price is large and S is more willing to wait, so B can purchase with a smaller probability without inducing S to cut for sure. Similarly, c will be larger if ρ, α, or C is large. In either of these cases, the price is large and B is less willing to buy. Thus, S must cut with a larger probability for B to be willing to pay.

3 The Dynamic Conservation Game

This insight from the static game carries over to the more realistic dynamic game. In the following, it is assumed that time is *continuous* and either player can act *at any time.* As soon as S has cut or B has paid, the game is over. Both players maximize the present-discounted value of their respective payoffs and $r > 0$ measures the common discount rate. The agreement between B and S can be interpreted as a sale or as a long-lasting rental arrangement.[2] With this, the game is a *stopping game* and payoffs are zero until the game

[2] There is no difference between the two in the present paper. In reality, a rental arrangement might be more realistic since it is less expensive for locals to protect the forest (Somanathan et al., 2009; Chhatre and Agrawal, 2008). This benefit is further analyzed in Harstad (2016), but that paper abstracts from most of

ends. The game is also *stationary* in that the subgame that remains at any time is identical and invariant in that time. For this reason, it makes sense to consider equilibria in stationary strategies that are independent of the time itself. Thus, as long as the game is being played, $b \in [0,1]$ measures the stationary *Poisson rate* at which B will pay at any point in time, while $c \in [0,1]$ measures the Poisson rate at which S will cut. The Poisson rate specifies the probability that a player will act over a marginal unit of time: i.e. the probability that B or S ends the game between time t and $t+\Delta$, divided by Δ, when $\Delta \to 0$.

Clearly, there is no equilibrium in which both $b \to \infty$ and $c \to \infty$, since S prefers to conserve if B is likely to pay. Hence, in this continuous-time game we can ignore the possibility that the two players might act at the exact same time.

PROPOSITION 2. *There is a unique stationary equilibrium, and it is in mixed strategies:*

$$\begin{aligned} b &= r\frac{C}{P-C} & \text{and} \quad c &= r\frac{P}{E-P} \\ &= r\frac{C}{(E-C)\alpha} & &= r\left[\frac{E}{(E-C)(1-\alpha)}-1\right]. \end{aligned} \tag{2}$$

Note that the comparative statics are similar to those in the static game, as presented by Proposition 1. If C is large, S is more tempted to cut, and B must and will pay with a larger probability. If E is large, B is tempted to pay and S can and will cut with a smaller probability, without inducing B to wait for sure.

The second line in (2) takes into account the endogenous price, as given by (1).[3] As in the static game, and Proposition 1, B is less likely to buy if the conservation value E is large, since the fact that the price is also larger, then, will motivate the seller to conserve in any case.

Since there is no equilibrium in pure strategies, there is a chance that S cuts before B has paid if just $P \in (C,E)$, which holds when $\alpha \in (0,1)$. The outcome would be efficient

the other issues studied in the present paper.

[3] Here it is assumed that the threat point in the negotiations is that S cuts with certainty. This assumption is reasonable as long as there is a tiny chance that S is of a "crazy" type that cannot or will not pay for conservation. This assumption contrasts the model of Harstad (2016), where it is instead assumed that S makes a take-it-or-leave-it offer regarding the price after B has contacted S, and that the threat point is to continue play rather than that S cuts with certainty. These assumptions would imply that any price $P \in [C,E]$ could be an equilibrium price, so the predictive power of the theory would be less.

($b \to \infty$) only if B had all the bargaining power in that $\alpha \to 0$. In this special case, S would cut at rate $rC/(E-C)$ but the forest would be conserved since B would immediately pay.[4]

3.1 Gradual Deforestation

Randomization is not necessary for the results above. It is well known that mixed strategies can be purified by introducing privately observed shocks (Harsanyi, 1973). Alternatively, one can let the forest be divisible. The owner may be able to cut any fraction she wishes, and the buyer can purchase less than the entire forest. If the good is divisible in this way, then randomization is not necessary for the equilibrium described above. To see this, assume that C, E, and P are all measured *per unit* of the forest.[5] Note that these linearities require that both players be risk-neutral and that marginal benefits do not change as the forest shrinks; these requirements may be reasonable if the forest for sale is relatively small. The linear payment is consistent with existing REDD agreements, which do specify payments that are linear in how much deforestation is reduced.[6] When the good is divisible in this way, c can be interpreted as the *fraction* of the forest that is cut in each period or, more generally, the *expected* fraction that is cut. Likewise, b can be interpreted as the expected fraction that is purchased in each period.

PROPOSITION 3. *Suppose the forest is divisible. The equilibrium in Proposition 2 survives if b and c are interpreted as the expected fractions that are bought and cut, respectively.*

In other words, the fraction that is cut at any moment, c, decreases in the conservation

[4] Although the equilibrium is in mixed strategies, the game is different from classic war-of-attrition models. War-of-attrition games were first studied by Maynard Smith (1974) in biological settings, but are often applied in economics. According to Tirole (1998:311), "the object of the fight is to induce the rival to give up. The winning animal keeps the prey; the winning firm obtains monopoly power. The loser is left wishing it had never entered the fight." Muthoo (1999:241) provides a similar definition. In this model, in contrast, the buyer is perfectly happy with the status quo, and he does not hope that the seller will act.

[5] That is, if the forest size is initially of mass 1, and S cuts a fraction x, then S gains xC and B loses xE. If B purchases a fraction y, B pays yP. See also the proof of the following proposition.

[6] For example, Norway's contract with Guyana specifies a payment of 5 USD per ton of CO2, multiplied with 100 ton CO2 per hectare of forest, in turn multiplied with an estimated (and partly negotiated) base line level of deforestation minus the actual level of deforestation (http://www.regjeringen.no/en/dep/md).

value E, and increases in the market value of logging, C. The expected fraction that is purchased is larger if the commercial value of logging is large, but smaller if the conservation value is large.

3.2 The Fate of the Forest

With a nondivisible forest, at every point in time there are three possible outcomes. The forest might have been logged, it might have been paid for, or the game is still being played. If the game has not already stopped, there is a chance that it will stop in the next period. Thus, the cumulated probability that the forest will have been cut before the end of some time T increases in T. Similarly, the cumulated probability that the forest will have been paid for before time T is also increasing in T. The sum of these cumulated probabilities approaches one as T goes to infinity: eventually, conservation either ends or it is paid for. These probabilities can be derived from Proposition 2: when $T \to \infty$, the probability that the forest is conserved forever. for example, is simply $b/\left(b+c\right)$. The probabilities are illustrated in Figure 1.

Proposition 4. *The expected fraction of the forest that will remain when time passes decreases in the environmental value E and increases in the market value of cutting, C:*

$$\frac{1}{1+\alpha+\left(E/C\right)\alpha^{2}/\left(1-\alpha\right)}\in\left(0,1\right).$$

The proposition holds whether the forest is indivisible or divisible, since Proposition 3 confirms that Proposition 2 will hold in both cases. The expression in Proposition 4 can represent the probability that the (indivisible) forest is conserved or the fraction of it that is conserved forever. Remarkably, this fraction is smaller if the environmental value, E, is large. The intuition is that when E is large, the price is higher, and then the buyer can buy at a slower rate and still ensure that the seller has an incentive to conserve. Thus, when E is large, it is more likely that S cuts before B pays.

An equally surprising result is that the forest is cut to a larger extent if C is small. Intuitively, if C is small, S is not very willing to cut, and, hence, B can pay at a slower rate

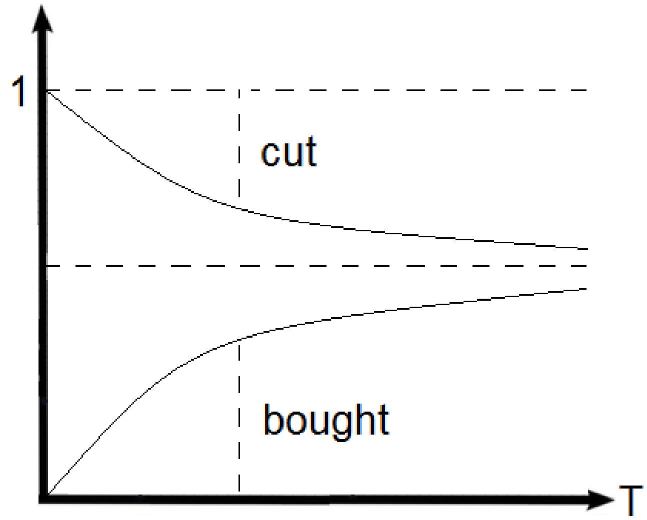

Figure 1: *The probabilities that the forest has been cut or purchased as functions of time*

without triggering S to cut with certainty. If the seller has most of the bargaining power ($\alpha \to 1$), the forest is eventually cut with probability one. If the seller's bargaining power is arbitrarily small ($\alpha \to 0$), however, the forest is eventually bought and conserved with probability one.

3.3 Incentives and Investments

Note that the equilibrium payoff for the seller is determined by the fact that one best response is to end conservation. Thus, S's payoff is C, even when S decides to wait. It follows that S has a large incentive to increase the market value of the forest products, for example by building roads or negotiating market access, even if S may not end up cutting. The intuition is that the larger C is, the larger is the probability that B will pay.

In contrast, S has no incentive to influence the environmental value of the forest, E. Even when the price is given by (1) and P increases in E, S has no incentive to influence E. The reason is that the larger is P, the smaller is the probability that B will pay.

The fact that S has absolutely no incentive to raise the quality of the good sold to the buyer is certainly at odds with the traditional economics literature. The literature on the hold-up problem emphasizes that a seller has insufficient incentives to invest, and will not invest the first-best amount, unless this investor has all the bargaining power when the price is negotiated (see Hart, 1995, for example). Here, in contrast, the seller has absolutely no incentive to invest, regardless of her bargaining power index α.

Just like S's payoff is pinned down by the fact that cutting must be a best response, B's payoff is pinned down by the fact that buying is always a best response. Thus, B's payoff is $-P$. Given (1), it is clear that B is better off if B has most of the bargaining power, and if C is small, since then the price is small. The level of C may be reduced if B succeeds in initiating a boycott that reduces the market value when S sells the forest products. While such a boycott increases B's payoff, the sum of payoffs, $C - P$, declines if C is reduced. Thus, a boycott reduces overall welfare: the smaller C means that the buyer can pay with a smaller probability without inducing S to cut, and thus it is less likely that the forest will be conserved forever. This fact follows from Proposition 4.

PROPOSITION 5. *The seller has strong incentives to raise the value of cutting, and no incentive to improve the environmental value. The buyer benefits from boycotting the forest products, but a boycott makes the buyer less likely to pay and it reduces overall welfare.*

Note also that the seller would have no incentive to invest in ecotourism or in her own environmental value, if either of these were possible. Such an investment would raise S's payoff when no action is taken, but it would reduce by the same amount the relative value of cutting, C. The two effects would cancel each other, so there are no incentives for S to make such an investment. Intuitively, the larger environmental value to S would mean that B could pay with a smaller probability without inducing S to end conservation.

4 Collective Action Problems and Remedies

4.1 Many Buyers

The model above can easily allow multiple buyers. To simplify, suppose there are n identical potential buyers. Thus, every $i \in N \equiv \{1, ..., n\}$ receives the payoff $-E$ when S cuts, the payoff $-P$ if i buys, and zero if $j \in N \backslash i$ buys or if S conserves. In the rental market, the payoffs are analogous. As before, let b represent the Poisson rate at which S is contacted by *some* buyer. Thus, in a symmetric equilibrium, every i contacts S at the rate b_i which satisfies $(1-b) = (1-b_i)^n \Leftrightarrow b_i = 1-(1-b)^{1/n}$.

Perhaps surprisingly, most of the results continue to hold:

PROPOSITION 6. *Suppose there are n identical potential buyers. There is a unique symmetric stationary equilibrium, and it is in mixed strategies. The seller sells at Poisson rate $b = rC/(E-C)\alpha$ and ends conservation at a Poisson rate that increases in n:*

$$c = r\left(\frac{P}{E-P} + \frac{(1-1/n)\,C}{(E-P)\,(P-C)}\right).$$

In comparison to Proposition 2, the result is disappointing. The only difference is that there is more cutting when $n > 1$. If more countries benefit from conservation, a planner should instead be more eager to conserve the forest, but the equilibrium outcome is the reverse. The rate at which some buyer (or a renter) contacts S is unchanged if n grows, but S cuts at a faster rate!

The intuition is the following. When n is large, every buyer i hopes that another buyer may contact S and pay for conservation. This hope reduces i's willingness to contact S and, for i to still be willing to pay, S must cut at a faster rate.

The outcome is still worse if the aggregate conservation value, say $\overline{E}$, is held constant while n increases (i.e., if the buyers go from acting collectively to acting independently). Then, $E = \overline{E}/n$ and, for a given P, S cuts even faster when n grows, since E also decreases. (However, when the equilibrium price decreases in E, this effect is somewhat but not fully mitigated.)

Nevertheless, the similarities to the one-buyer case may be more surprising than the differences. First, b is independent of n, given the price. The reason is that S is willing to randomize only if the rate at which *some* buyer will pay, multiplied by the price, makes S indifferent. Second, in equilibrium, every buyer receives the payoff pinned down by the payoff he would receive if he were to contact S immediately and in isolation. Thus, in equilibrium buyers do not gain from the presence of other buyers: the benefit that the other countries may pay for conservation is canceled by the cost of the faster logging rate.

4.2 Coordination vs. Cooperation

When there are multiple buyers, the inefficiency worsens and equilibrium conservation is reduced. The multiple potential buyers would then clearly be better off if they coordinated by selecting one of them to be the buyer playing the single-buyer game, analyzed above.

Alternatively, the multiple buyers may decide to "cooperate" by acting as a single player. Compared to coordination, cooperation has the benefit that the coalition of buyers might buy with a greater probability than would a single buyer. The disadvantage, however, is that the seller can charge a higher price when the buyer's value of conservation increases from E to nE.

It turns out that the benefit and the costs cancel each other, so that the set of buyers are equally well off if they coordinate as if they cooperate. The seller is also indifferent about the two alternatives, since the seller's payoff is always pinned down by the fact that cutting remains a best response.

Proposition 7. *The buyers benefit equally much if they solve their collective action problem by coordination or by cooperation.*

Coordination or cooperation is necessary to solve the collective action problem when there are multiple potential buyers, but solving the collective action problem only means that the game is reduced to one between a single seller and a single buyer. This problem continues to be inefficient, as stated by Propositions 2-6, but it can be addressed by returning to the source of the problem, as will now be discussed.

4.3 Funds to Compensate for Conservation

The source of the conservation contradiction lies in the expectations. The owner conserves if she expects the buyer to pay, but the buyer prefers to change his mind by not paying if the seller in any case conserves.

Another interpretation of the problem is that it is due to time inconsistency: the buyer would like to promise future payments, such that the seller will conserve already today. But when the future arrives, the buyer finds it optimal to postpone these payments.

The natural solution to time inconsistency problems is to introduce some kind of commitment device. If the buyer can make the future payment credible, then the forest will indeed be conserved today. In fact, if just a fund of size F is released (conditional on conservation) at some future time $T > 0$ with probability $q \in (0, 1]$, the owner will find it better to conserve today if only the expected value of the fund F is larger than the benefit of ending conservation, C. This condition amounts to $qFe^{-rT} \geq C$.

PROPOSITION 8. *If the buyer pledges a fund F to be released at time T with probability q, the seller conserves already today if and only if:*

$$F \geq C/qe^{-rT}$$

The real benefit of having multiple buyers may thus be that they can sign a multilateral treaty that commits each other to future policies. It is difficult for a single country to commit itself to a future policy, but if a deviation from the multilateral agreement requires the country to walk away from an international treaty, some real (political) costs will at least be entailed.

Proposition 8 states that the required size of the fund F is C/qe^{-rT}. If the fund is smaller, the seller strictly prefers to end conservation immediately, so the buyer loses E. If the fund is larger than C/qe^{-rT}, the seller conserves but the buyer can obtain the same outcome at a lower cost. Thus, B prefers the fund to be of size $F = C/qe^{-rT}$. In other words, conservation will succeed today even if the world is unable to cash out immediately, and even if the probability that they will eventually do so is less than one, if just the expected funds to be pledged is higher in these circumstances.

Naturally, if some of the parameters in the model were uncertain, it would be optimal for the buyer to commit to a fund that is somewhat larger than the expectation of C/qe^{-rT}, since the cost of setting F too low is much larger than the cost of setting F slightly above C/qe^{-rT}.

5 Conclusions

This paper discusses a continuous-time model where the owner must at every point in time decide whether to continue conserving a forest. Conservation is assumed to be costly because of monitoring/protection costs or because of forgone profit from logging/agriculture. Thus, conservation is worthwhile to the owner only if it can be expected that a buyer, or the "North," will eventually pay for such conservation. The buyer, however, does not find it necessary to pay for conservation as long as the owner conserves in any case. This contradiction implies that there is a fundamental inefficiency in the market for conservation, and that conservation cannot succeed with probability one.

Based on this inefficiency (which is also analyzed in Harstad, 2016), the present paper makes a number of contributions. First, it shows that the conservation contradiction implies that the forest stock will gradually decrease to a level that is smaller if the environmental value is large. This perverse effect is explained by the fact than a larger conservation value leads to a larger equilibrium price, and at the larger price the seller is willing to conserve even if the buyer is less likely to pay. Second, the owner of the forest has absolutely no incentive to invest in enhancing the environmental value, since a higher price for conservation is accompanied by a smaller probability that the buyer will actually pay. The inefficiency is thus more harmful than in the standard hold-up problem, where a seller has insufficient incentives to invest unless it has all the bargaining power when the price is negotiated (Hart, 1995). Third, while a large number of potential buyers imply that the problem is worsened, the collective action problem is solved equally well by coordination (where a single buyer is selected to deal with the seller) as well as cooperation (where all buyers act together as a single player).

The analysis provides a number of other lessons for policy as well.

First, the solution lies in the source of the problem: the expectations. To succeed with conservation, forest owners must trust that future compensation will indeed be forthcoming. If future compensation is credible, conservation will succeed already today. It is often difficult for national policy makers to succeed in pre-committing to future policies. One way of pre-committing is to sign international treaties that require countries to pay for conservation or to donate resources to a fund that is to be used for such compensations. The possibility to commit to such a future policy may be the real benefit of having multiple potential buyers.

Second, the analysis reveals that the problem of deforestation may *not* be that the seller is unwilling to accept the equilibrium price in return for conservation. Instead, it is the buyer that is unwilling to pay this price, since the buyer hopes and expects that the seller may be willing to conserve in any case. Thus, a policy that succeeds in reducing the equilibrium price will enhance efficiency: a lower price will raise the probability that the buyer(s) pay, and reduce the equilibrium rate of cutting. The buyer benefits from such a change, while the seller is indifferent, since the seller's payoff is pinned down by the fact that cutting is a best response. Thus, by letting the buyer have most of the bargaining power, efficiency is enhanced. This contradicts the traditional economics literature on normal goods, where the allocation of bargaining power influences the price without having unambiguous effects on welfare. In reality, the buyers' bargaining power may be strengthened by building a reputation or establishing a norm regarding the price for conservation, or if multiple buyers sign treaties and use each other as third-party enforces. Thus, also this policy solution suggests that the multiplicity of buyers can be turned into the solution rather than being left as part of the problem.

6 Appendix: Proofs.

Proof of Proposition 1. The buyer is (weakly) better off waiting rather than buying if and only if:

$$
\begin{aligned}
-cE &\geq -(1-c)P - c(\rho E + (1+\rho)P) \Rightarrow \\
c &\leq \frac{P}{(1-\rho)E - \rho P} \\
&= \frac{(1-\alpha)C + \alpha E}{(1-(1+\alpha)\rho)E - \rho(1-\alpha)C}.
\end{aligned}
$$

Similarly, the seller is (weakly) better off waiting rather than cutting if and only if:

$$
\begin{aligned}
bP &\geq (1-b)C + b(\rho C + (1-\rho)P) \Rightarrow \\
b &\geq \frac{C}{\rho P + (1-\rho)C} \\
&= \frac{C}{\rho\alpha E + (1-\rho\alpha)C}.
\end{aligned}
$$

With b on a horizontal axis, and c on a vertical axis, B's best response function equals 0 before it jumps to 1 at $c = P/(1-\rho)E - \rho P$, while S's best response function is downward-sloping and horisontal only when $b = C/\rho P + (1-\rho)C$. Thus, the two best-response curves cross only once, implying a unique equilibrium. □

Proof of Proposition 2. This proof is a simplified version of the proof of Proposition 6, and it is thus ommitted. □

Proof of Proposition 3. In the proof of Proposition 6, below, b and c can be interpreted as fractions that are bought and cut without changing the proof. This establishes that the equilibrium described in Proposition 2 continues to hold with these interpretations of b and c. When the good is divisible, we may have other MPEs as well, if strategies can be conditioned on the fraction consumed so far. However, note that the amount of the good that is left is not "payoff-relevant" because x_t and y_t drop out when we compared payoffs above. Thus, if one player's strategy is not contingent on the level of the remaining stock, then the other player cannot benefit from such a contingency, either. In this way, the size of the forest is not payoff-relevant, and the strategies in a Markov-perfect equilibrium should not be contingent on it (following the reasoning of Maskin and Tirole, 2001). By this argument, the Markov-perfect b and c are unique for $P \in (C, C/\delta) \cup (C/\delta, D+E)$ and in line with Proposition 2. $\square$

Proof of Proposition 4. The proof follows directly when substituting the equilibrium values of b and c into the fraction $b/(b+c)$. $\square$

Proof of Proposition 5. The proof follows directly from the fact that a best response for B is to pay and receive $-P$, while a best response for S is to cut and receive C. $\square$

Proof of Proposition 6. The aggregate $b = \sum_{i \in N} b_i$ that makes S willing to randomize is given by:

$$\begin{aligned} C &= \int_0^\infty Pbe^{-t(r+b)}dt = \frac{bP}{r+b} \Rightarrow \\ b &= \frac{rC}{P-C}. \end{aligned}$$

For $i \in N$, the rate at which someone else buys is $b_{-i} \equiv b - b_i$. Buyer i is thus willing to randomize when:

$$\begin{aligned} P &= \int_0^\infty (cE + b_{-i} \cdot 0)\, e^{-t(r+b_{-i}+c)}dt = \frac{cE}{c+b_{-i}+r} \Rightarrow \\ c &= \frac{P(b_{-i}+r)}{E-P} = \frac{P(b(n-1)/n+r)}{E-P}, \end{aligned} \tag{3}$$

where the equality $b_i = b/n$ is used since every b_{-i} must be the same in order for (3) to hold for all $i \in N$. Substituting in for (1) completes the proof. $\square$

Proof of Proposition 7. The simplest way of proving Proposition 7 is to note that coordination is better than cooperation for the n buyers if and only if:

$$
\begin{aligned}
-(1-\alpha)C-\alpha E-(n-1)E\frac{c}{b+c+r} &> -(1-\alpha)C-\alpha E n \Rightarrow \\
-(1-\alpha)C-\alpha E-(n-1)E\frac{\frac{(1-\alpha)C+\alpha E}{E-(1-\alpha)C-\alpha E}}{\frac{C}{(1-\alpha)C+\alpha E-C}+\frac{E}{E-(1-\alpha)C-\alpha E}} &> -(1-\alpha)C-\alpha E n \Rightarrow \\
(n-1)E\frac{\frac{(1-\alpha)C+\alpha E}{E-(1-\alpha)C-\alpha E}}{\frac{C}{(1-\alpha)C+\alpha E-C}+\frac{E}{E-(1-\alpha)C-\alpha E}} &< \alpha E(n-1) \Rightarrow \\
\frac{\frac{(1-\alpha)C+\alpha E}{E-(1-\alpha)C-\alpha E}}{\frac{C}{(1-\alpha)C+\alpha E-C}+\frac{E}{E-(1-\alpha)C-\alpha E}} &< \alpha.
\end{aligned}
$$

This condition is independent of n. Since the left-hand side must equal the right-hand side when $n = 1$ (cooperation and coordination are equivalent when $n = 1$), the same must hold for every $n > 1$ since n is not a part of the inequality. □

Proof of Proposition 8. The proof follows from the text. □

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