The Market for Conservation and Other Hostages

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Abstract

A "conservation good" (such as a tropical forest) is owned by a seller who is tempted to consume (or cut), but a buyer benefits more from conservation. The seller prefers to conserve if the buyer is expected to buy, but the buyer is unwilling to pay as long as the seller conserves. This contradiction implies that the market for conservation cannot be efficient and conservation is likely to fail. A leasing market is inefficient for similar reasons and dominates the sales market if and only if the conservation value is low, the consumption value high, and the buyer's protection cost large. The theory explains why optimal conservation often fails and why conservation abroad is leased, while domestic conservation is bought.

Key words: Conservation, deforestation, dynamic games, sales v rental markets

JEL: Q30, Q23, D78, D62, H87

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1 Introduction

This paper introduces the notion of "conservation goods" and shows how they differ fundamentally from traditional goods in dynamic settings. Traditional goods are purchased by buyers who intend to consume the good: trade is typically predicted to take place immediately if the buyer's consumption value is larger than the seller's. For conservation goods, in contrast, the buyer is satisfied with the status quo: he does not desire to consume the good, but only to prevent the seller from consuming it in the future. This feature implies that the market for conservation goods tends to be inefficient. I find the inefficiencies to arise in rental markets as well as in sales markets; a comparison between the two generates new insight for when leasing is preferred to sales.

Tropical forests are conservation goods - in the jargon of this paper. On the one hand, the South benefits from selling the timber and clearing the land for agriculture or oil extraction. On the other, the North prefers conservation in the South because the tropical forests are among the most biodiverse areas in the world, they are inhabited by indigenous people, and deforestation contributes to 10-20 percent of the world's carbon dioxide emissions, which cause global warming.[1] Negative externalities from forest loss and degradation cost between \$2 trillion and \$4.5 trillion a year according to *The Economist.*[2] With this reasoning, President Rafael Correa of Ecuador launched in 2007 the Yasuni-ITT Initiative to raise \$3,6b to protect Yasuni National Park, one of the most biodiverse spots on Earth. But in 2013 the plan was scrapped and the Park opened to oil drilling, after less than a tenth of the requested amount had been pledged and less than half a percent received (*Reuters*, Aug. 16, 2013).

When the North's conservation value is larger than the South's value of logging, bargaining in the spirit of Coase (1960) would ensure that the forest is preserved: the North should simply buy the forests or pay the current owners for conservation. From this perspective it is puzzling why the North is not buying conservation on a large scale – despite having established the UN-REDD program – and that it continues to let about 13 million hectares

[1] The estimates have varied within this interval since IPCC (2007, see also 2013).

[2] September 23, 2010, where *The Economist* cites a UN-backed effort, The Economics of Ecosystems and Biodiversity (TEEB)

of forest disappear every year (FAO, 2010). Deforestation rates can be halved for as little as \$5 per ton CO_2 according to Stern (2008), and, where it is tried, such payments have been successful at reducing deforestation.[3]

Conservation agreements may be the most efficient climate policy, also when they are interpreted more broadly. This author has in this *Journal* argued that a first-best climate policy is to buy fossil fuel deposits in free-riding countries, with the intention of conserving rather than exploiting these deposits (Harstad, 2012). Such a policy can successfully reduce carbon leakage as well as other inefficiencies associated with traditional climate policies focusing on the demand side of the equation. But if paying for conservation is the ideal climate policy - the puzzle is why we do not already observe this in practice.

There are also many other examples of payments for environmental/ecosystem services (Engel et al. 2008). In the United States, The Nature Conservancy frequently uses land acquisition as a tool of its conservation effort. Unfortunately, the outcome is often inefficient. As a recent example, villagers on the Solomon Islands had agreed with the Earth Island Institute to protect bottlenose dolphins in return for \$2.4 million SBD (Solomon Island Dollars). When the pay was delayed, the villagers retaliated by slaughtering as many as 900 dolphins.[4]

This paper aims at explaining these puzzles and to investigate why and when the market for conservation is inefficient. The answer points to the nature of the good: a conservation good is purchased only when the seller is expected to consume, but the seller consumes only when buyers are unlikely to pay. This contradiction implies that the equilibrium must be inefficient and (if the good is indivisible) in mixed strategies. As far as the model is concerned, the conservation good can also be a piece of art, historical ruins, real captives or hostages: as long as the good is conserved, the buyer may be in no hurry to pay.

[3] Hansen et al. (2013) find evidence that tropical deforestation has declined only in Brazil; the main partner of Norway's REDD fund. The recent emergence of REDD (Reducing Emissions from Deforestation and Forest Degradation) funds does provide financial incentives to conserve, but REDD is a recent phenomenon and offered to a very limited extent. The 2010 Cancun Agreements (UNFCCC, 2010) recognize the importance of reducing deforestation and forest degradation, but do not specify who should pay and how this should be implemented.

[4] The Epoch Times, January 24th, 2013. Webpage: http://www.theepochtimes.com/n2/world/solomon-island-villagers-kill-900-dolphins-in-retaliation-339833.html. I am grateful to Atle Guttormsen for suggesting the story.

To formalize the market for conservation, I start by presenting a dynamic model with a seller (S), a buyer (B), and a good (e.g., the forest). In each period, B decides whether to buy. As long as B has not yet bought, S has the possibility of consuming - or "cutting." The game is a stopping game which ends after sale or consumption. The only novelty in the game is that B benefits if S conserves.

As in most games with an infinite time horizon, there are multiple subgame-perfect equilibria, and some of these are efficient. However, if we require the equilibrium to be either stationary, Markov-perfect, or renegotiation-proof, then the equilibrium is essentially unique. But there is no good equilibrium in pure strategies. The buyer cannot *buy* with probability one, since S would then conserve and there would be no need to buy; a contradiction. The seller cannot *cut* with probability one, since B would then hurry to buy and S would conserve in the meantime; another contradiction. Instead, the equilibrium must be in mixed strategies. In equilibrium, S is more likely to cut if the conservation value is low and, perversely, B is more likely to buy if the value of cutting is high.

Since the sales market is inefficient, I also consider a rental market where B can temporarily pay S for conservation. For the same reasons as before, it cannot be an equilibrium that B rents with a very high probability, since S would then always conserve, making it unnecessary for B to rent. The inefficiencies are thus similar to the sales market. But the two markets are not identical and, when compared, the model predicts the rental market to be both better and the equilibrium choice if and only if the conservation value is small relative to the consumption value, while B's maintenance or protection cost is high relative to S's protection cost. In other words, domestic conservation will be bought, while conservation across the border (which would require high protection costs) will be rented.[5]

This paper does *not* aim at explaining deforestation per se. There are already several convincing explanations pointing to corruption, electoral cycles, unclear property rights, multiple users and owners, multiple buyers, leakage, and the difficulties in monitoring and enforcing contracts.[6] Despite these difficulties, conservation agreements appear to work

[5]Somanathan et al. (2009) do find that governments that are more local protect forests at lower costs.

[6]See, for example, Alston and Andersson (2011) and Angelsen (2010), and the references therein. For empirical studies of the determinants of deforestation, see Burgess et al. (2011), Damette and Delacote (2012), or, for an earlier overview, Angelsen and Kaimowitz (1999).

where they have been tried, and they may also induce multiple users to act as a single player (Phelps et al. 2010). The remaining puzzle is not why there is deforestation without an agreement, but why the agreements are absent. Even when we abstract from all the mentioned obstacles, the current paper shows that inefficiencies continue to exist in the market for conservation, because they are fundamentally tied to the nature of the good.

The effects analyzed in this paper are not discussed elsewhere in the environmental economics literature, to the best of my knowledge. On the contrary, it is frequently argued that the expectation of a future environmental policy leads to less conservation today (Kremer and Morcom, 2000) or a worse environment ("the green paradox"; Sinn 2008 and 2012). In this paper, in contrast, the owner of a resource may conserve today exactly because a future environmental policy is anticipated. The reason for the conflicting results is that in the present paper, the owner is (more than) fully compensated for conservation and thus benefits when the future policy arrives.

Theoretically, bargaining between a buyer and a seller tends to be efficient and without delay when information is complete.[7] While the reasoning in this paper requires a dynamic framework, the mechanism is different from the literature on durable goods markets, where the Coase conjecture, for example, requires more than one buyer valuation.[8] My model also differs from classic war-of-attrition models, where every player prefers the opponent to end the game.[9] Papers on inspection games (surveyed by Avenhaus et al., 2002) also find that the equilibrium must be in mixed strategies, but that literature relies on asymmetric information. With asymmetric information, Gradstein (1992) has pointed out that private provision of public goods will be inefficient and with delay. In contrast to all these literatures, in the market for conservation goods, the buyer prefers the status quo rather than to buy.

The present paper also contributes to the literature on sales in the presence of external-

[7] See the survey by Osborne and Rubinstein (1990), which also discusses exceptions.

[8] As conjectured by Coase (1972) and shown by Bulow (1982), the seller of a durable good has an incentive to reduce the price over time. For this effect, it is essential that there is more than one buyer valuation. In this paper, there is only one buyer type and the price does not drop over time.

[9] 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 paper, in contrast, the buyer is perfectly happy with the status quo, and he does not hope that the seller will act.

ities: the game here would remain essentially identical if, as an alternative to cutting the forest, the owner could sell the forest to a logger, generating a negative externality on the buyer interested in conservation. Sales in the presence of externalities were first discussed by Katz and Shapiro (1986) and later analyzed by Jehiel et al. (1996), who let the seller commit to a sales mechanism. Jehiel and Moldovanu (1995a and 1995b) present equilibria with inefficiencies and delay - if the time horizon is finite or buyers have bounded recall. In other cases, Björnerstedt and Westermark (2009) show that there cannot be any delay in these models when attention is restricted to stationary strategies: trade occurs as soon as the seller is matched with the "right" buyer. This result is nonrobust, as the current paper shows. Formally, the main difference is that I endogenize matching between the buyer and the seller. Rather than imposing an exogenous matching, as in the literature just mentioned, I follow Diamond (1971) by letting the buyer choose whether to get in touch with the seller.[10] The nonrobustness is obviously a two-edged sword, implying that the delay emphasized in this paper would not survive if a buyer was always forced to meet with the seller. However, it is quite standard in the literature on international environmental agreements to assume that participation, i.e., to be present at the bargaining table, is both voluntary and necessary for negotiations to proceed.[11] Countries can thus free-ride simply by not showing up at the bargaining venue. This literature is nevertheless predicting full cooperation if there is as few as two parties. That conclusion does not hold for agreements on conservation (where some player prefers the status quo).

Finally, the paper contributes to the literature comparing buying and leasing arrangements. On the one hand, my assumption that the initial owner often has a lower cost of protecting or maintaining the good is recognized by textbooks in finance: "under a full-service lease the lessor provides maintenance; in many cases he may be in a better position to provide such service" (Levy and Sarnat, 1994:662). This argument points to an advantage of leasing arrangements. On the other hand, this paper uncovers a new drawback of leasing

[10] Jehiel and Moldovanu (1999) also endogenize matching when allowing for resale and externalities: When the *seller* can reach out to any (set of) buyer(s), they show that the identity of the final buyer is independent of the initial owner. This is in contrast to my paper, and the explanation is, once again, that in my model the buyer can decide whether to get in touch with the seller.

[11] See the survey in Barrett (2005). See also Dixit and Olson (2000) for public good provision agreements, or Battaglini and Harstad (2015) for a dynamic emission game with coalition formation.

markets: since the market for conservation is not efficient, payoffs may be higher if the parties trade once and for all rather than continue forever in the inefficient market. Combined, this generates a new trade-off which suggests that goods with high conservation values should be purchased, while leasing conservation is better for geographically remote areas, for which the buyer would face relatively high protection costs.[12]

The next section presents and analyzes the inefficient sales market for conservation goods. Section 3 repeats the exercise for rental arrangements and compares the two markets. In order to arrive at the main results in a rapid and efficient manner, I start out by restricting attention to stationary strategies, and I take the prices as exogenously given. As far as this paper is concerned, it is in fact irrelevant whether the price for conservation is exogenously given or an endogenous outcome of some bargaining game between the buyer and the seller. The intriguing results of the paper arise as long as (a) the price is larger than the seller's benefit of cutting, and (b) trading at this price is voluntary. Assumptions (a) and (b) are crucial as well as strong, and they are not satisfied in all games, but they are realistic, in my view, and Sections 4.1-4.2 present two alternative bargaining procedures which both imply (a)-(b). Section 4.3 explains that efficient (non-stationary) subgame-perfect equilibria do exist but these are neither Markov-perfect nor renegotiation-proof. Section 5 allows for continuous time and multiple buyers or sellers, but it nevertheless concludes that the stable equilibria coincide with the one-buyer-one-seller situation investigated in Sections 2-3. After a brief concluding section, Appendix presents all proofs.

[12] The economics literature comparing sales and leasing focuses on rather different trade-offs. Bulow (1982) showed how leasing arrangements can solve the monopolist's problem as illustrated by the Coase conjecture, since the produced quantity is then always returned to the seller and a later expansion of the quantity would thus reduce the price and harm the seller. Furthermore, if the seller possesses private information, then adverse selection, or the market of the lemons, can be avoided with leasing contracts (Hendel and Lizzeri, 2002; Johnson and Waldman, 2003). Johnson and Waldman (2010) compare this benefit with the moral hazard that occurs when the lessee does not own the good himself (discussed by Henderson and Ioannides, 1983; Smith and Wakeman, 1985; Mann, 1992). If it is the buyer who possesses private information, then leasing today reveals a high willingness to pay and the price may thus increase tomorrow (Hart and Tirole, 1988). This "ratchet effect" creates inefficiencies that are avoided in the sales market. (For textbook discussions, see Tirole, 1998, or Bolton and Dewatripont, 2005.) None of these benefits or drawbacks is present in this paper.

2 The Sales Market

2.1 Stage Game

There is one seller (S; "she"), one buyer (B; "he"), and one indivisible good initially owned by the seller. First, the buyer decides whether to buy the good. If he does, the game ends. If he does not buy, the seller decides whether to consume or conserve the good.

The game is quite standard, and its terminal payoffs are illustrated in Figure 1. If the buyer purchases the good, he enjoys the direct benefit D although he must pay the price P, which in turn equals the seller's payoff. If the buyer does not buy and the seller consumes the good, the seller enjoys the payoff $C > 0$. All parameters are common knowledge.

The only novelty in this stage game is that the buyer enjoys some benefit from the existence of the good, whether or not it is purchased. This "existence" value, or perhaps "environmental" benefit, is represented by $E > 0$. Payoffs are normalized such that if B does not buy and S does not consume, both payoffs are zero. Thus, the existence value E is experienced as a loss by B if and only if S consumes. A positive existence value is reasonable for all examples mentioned in the Introduction. To fix ideas and point to an important example, I will refer to the good as a unit of forest and S's consumption as cutting.

Quite generally, D measures the difference in utility for B between owning and having the good conserved by S. For a traditional good, such as the purchase of a car, $D > 0$ and $E = 0$. But for a "pure" conservation good, where B enjoys the full value of the good whether B buys or S conserves, then $E > 0$ and $D = 0$. If there is a cost of maintaining or protecting the forest, then B may actually prefer that S own and conserve it: the maintenance cost can be measured by $-D$. Thus, $D < 0$ is quite reasonable when it comes to conservation goods. Section 3 allows B to pay S to conserve the good as a leasing arrangement (then, B saves the protection cost $-D$). The model can easily be reformulated to permit a maintenance cost also for the seller (see footnote 23). In this section, parameter D plays a minor role and the reader is free to simplify by assuming that $D = 0$.

Note that the addition of E does not alter the play of the static game: it is a unique best response for S to consume, given that she reaches her decision node, and (therefore) it is a unique best response for B to buy for every $P \in (C, D + E)$. To describe the equilibrium

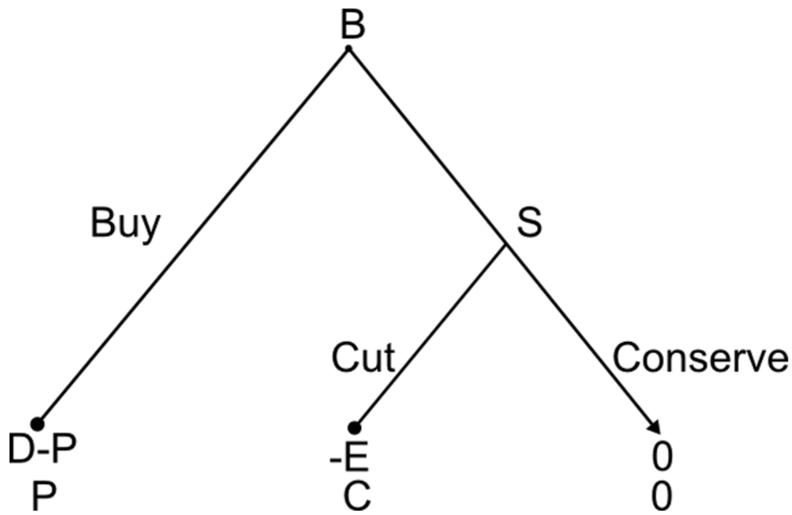

Figure 1: *If B does not buy, S decides whether to cut. The terminal nodes present the buyer's payoff, then the seller's payoff.*

formally, let B's strategy simply be the probability that he buys, $b \in [0,1]$, while S's strategy is the probability that she cuts, $c \in [0,1]$, given that she reaches her decision node.

PROPOSITION 0. *In the static version of the game, the unique subgame-perfect equilibrium is $b = c = 1$ if $P \in (C, D+E)$.*

The origin of the price P is actually irrelevant for the results of this paper: it can be exogenously given or an endogenous outcome of a bargaining game between B and S. While Sections 2 and 3 treat P as a 'black box', Section 4 presents alternative ways of endogenizing it. In particular, Section 4.1 assumes that B first decides whether to negotiate with (or "contact") S. For example, the buyer (as well as the seller) may need to show up at the bargaining venue. If he does, the two negotiate the sales price P. When we 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, then the negotiated price is:

$$P = (1-\alpha)\,C + \alpha\,(D+E) \in [C, D+E]\,. \qquad (1)$$

If the equilibrium price is instead coming 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:

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

Note that the motivation for trade depends on the parameters. If $P < D$, as for traditional goods, the buyer buys because the benefit D is larger than the price. In contrast, if $D < P < D + E$, the buyer would prefer the status quo, and the purchase gives the buyer a negative payoff - but in equilibrium the buyer buys to prevent the seller from cutting. Thus, the good is a conservation good, or a "hostage": it is the threat of cutting which makes B pay. When the price is given by (1), the inequalities $D < P < D + E$ hold for every $\alpha \in (0,1)$ if just $D < C < D + E$.

Definition. The good is a *conservation good* if $D < C < D + E$.

2.2 The Dynamic Sales Game and Equilibrium

Consider the stage game above and suppose that the game ends if the buyer buys or the seller cuts. If no such action is taken, the forest is conserved and the game continues to the next period with the identical stage game. The dynamic game is thus a quitting or stopping game which continues until one player deliberately stops.

As before, payoffs are normalized to be zero unless the game stops. Now, the existence value E, for example, should be interpreted as the present discounted cost of losing the forest's conservation value forever. The common discount factor is $\delta \in (0,1)$, so if the forest is cut at time t, the present-discounted value of this cost measured at time zero is $\delta^t E$. Parameter C can be interpreted as the market value of the timber when the forest is cut, plus the present-discounted value of the agricultural crops that thereafter can be grown on the land. Parameter D, or $-D$, may be interpreted as the present discounted cost to B from protecting the forest forever after his purchase. Parameters are assumed to be constant over time for simplicity, but this assumption can be relaxed (see footnote 17).

A player's strategy is a mapping from the set of histories to a probability for stopping the game when this player has the possibility to act. A player can act only if no player has already acted, so the set of relevant histories is simply summarized by time. There are many subgame-perfect equilibria in this game, and some of them are efficient; see the discussed in Section 4.3. To make reasonable predictions for the outcome of the game, several refinements could be considered. It turns out that the set of renegotiation-proof equilibria, the set of Markov-perfect equilibria, and the set of stationary equilibria essentially coincide and permit a unique equilibrium. Section 4.3 explains this in detail; for now, I take the shortcut of simply restricting attention to stationary equilibria. After all, every pair of subgames starting at times t and t' are identical and there is no reason that the strategies should be contingent on the date. (If they were, the equilibrium would be neither Markov-perfect nor renegotiation-proof, as explained in Section 4.3.) With this refinement, an equilibrium is simply summarized by the stationary pair (b, c).

If $C > D + E$, no price can make trade mutually beneficial. If $D > P$, as for traditional goods, it is easy to see that B prefers to buy immediately and with probability one, so $b = 1$ in equilibrium. Thus, I henceforth consider conservation goods satisfying $D < C < D + E$, implying $D < P$ when S is willing to trade. For such conservation goods, it turns out that the equilibrium must be in mixed strategies.

PROPOSITION 1. *Suppose* $\delta > C/(D+E)$.[13] *The strategies* (b, c) *constitute an equilibrium if and only if:*

$$\begin{array}{llllll} \text{(i)} & b = 1 & \textit{and} & c = 1 & \textit{if} & P \in \left[C, \frac{C}{\delta}\right); \\ \text{(ii)} & b = 1 & \textit{and} & c \in \left[\frac{(1-\delta)(P-D)}{E-\delta(P-D)}, 1\right] & \textit{if} & P = \frac{C}{\delta}; \\ \text{(iii)} & b = \frac{C}{P-C}\left(\frac{1-\delta}{\delta}\right) & \textit{and} & c = \frac{(1-\delta)(P-D)}{E-\delta(P-D)} & \textit{if} & P \in \left(\frac{C}{\delta}, D+E\right); \\ \text{(iv)} & b \in \left[0, \frac{C}{P-C}\left(\frac{1-\delta}{\delta}\right)\right] & \textit{and} & c = 1 & \textit{if} & P = D+E. \end{array} \tag{2}$$

When $C > \delta P$, then S prefers cutting to selling in the next period, so B needs to buy with probability one to save the forest. However, if P or δ is larger (f.ex., if $\delta \to 1$), then case (iii) is most reasonable. In this situation, there is no equilibrium in pure strategies: If B bought for sure, S would prefer to conserve rather than cut, implying that B would not need to buy - a contradiction. If B never bought, S would always cut, but then B would prefer to buy - another contradiction. The only equilibrium is in mixed strategies where B buys with

[13] If $\delta < C/(D+E)$, the unique equilibrium is trivially $b = c = 1$, since there is no price that B is willing to pay which makes S willing to conserve at the cutting stage.

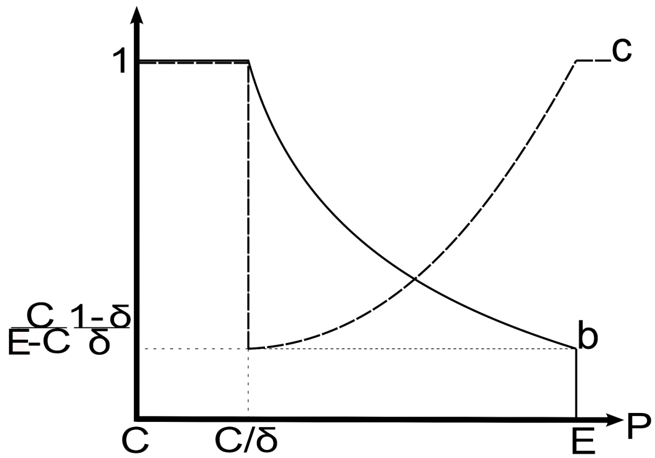

Figure 2: *The buying and cutting probabilities as functions of P (curves drawn for $D = 0$)*

a probability which is such that S is just indifferent between cutting and conserving, and S cuts with a probability which makes B just indifferent between buying and not buying.

This reasoning explains the comparative static. If the seller's benefit of cutting, C, is large, then she becomes tempted to cut and B must buy with a larger probability, according to the above results. It is thus more likely that the buyer will purchase a forest, with the intention of conserving it, if the forest is actually quite profitable to cut. When P is large, the buyer becomes less tempted to buy and S must thus cut with a higher probability to make B willing to buy. Furthermore, a high P makes the seller more tempted to wait for a sale, and thus the buyer buys with a smaller chance in equilibrium. The effects of P are illustrated in Figure 2.

Proposition 1 holds whether the price is exogenous or endogenous. In particular, we can assume (as in Section 4.1) that if B contacts S, then the parties negotiate the price. Under the (credible) threat that S will cut unless B buys, the generalized Nash bargaining solution predicts that the price is given by (1), above. A large P is then driven by the seller's large bargaining power index, α, or by the buyer's high willingness to pay, $D+E$. Referring to Proposition 1, case (iii) is the relevant one if:

$$P \in \left(\frac{C}{\delta}, D+E\right) \Leftrightarrow \alpha \in \left(\frac{1-\delta}{\delta}\frac{C}{D+E-C}, 1\right) \text{ under (1),}$$

which holds for every $\alpha \in (0,1)$ when $\delta \to 1$.

2.3 Purification and Gradual Cutting

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 conservation good 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, D, E, and P are all measured per unit of the forest.

Note that these linearities require that both players be risk-neutral and that marginal benefits do not change as the forest shrinks; this may be reasonable if the forest for sale is relatively small. A linear payment is consistent with existing REDD contracts, which do specify payments that are linear in the deforestation reduction.[14]

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.

COROLLARY 1. *Suppose the good is divisible. The equilibria in Proposition 1 and Corollaries 1 and 2 survive if b and c are interpreted as the expected fractions that are bought and cut, respectively.*[15]

[14] 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).

[15] To see Corollary 1, let x_t be the size of the forest at the start of period t, while y_t is the size of the forest at the subsequent interim cutting stage. Given b and c, we have $\mathrm{E}y_t = x_t(1-b)$ and $\mathrm{E}x_{t+1} = y_t(1-c)$. The buyer prefers buying now rather than in the next period if and only if:

$$x_t(D-P) \geq x_t(-cE + (1-c)(D-P)),$$

while S prefers cutting to conserving if and only if:

$$y_t C \geq \delta b y_t P + \delta(1-b) y_t C.$$

Note that x_t and y_t drop out, leaving the proof of Proposition 1 unchanged.

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 1.

2.4 The Fate of the Forest

At every point in time, there are three possible outcomes. The forest may have been cut, it might have been bought, or the game is still in play. 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 period t increases in t. Similarly, the cumulated probability that the forest will have been purchased before the end of period t is also increasing in t. The sum of these cumulated probabilities approaches one as t goes to infinity: eventually, the forest is either purchased or cut. These probabilities can be derived from Proposition 1 and they are illustrated in the Figure 3.[16]

COROLLARY 2. *The conservation good exists with a probability that declines over time to the probability that it is eventually purchased. When $\delta \to 1$, this probability is*

$$\frac{E/(P-D)-\delta}{E/(P-D)-\delta+\delta P/C-1}=\frac{1}{1+(1-D/C)\,\alpha+(E/C)\,\alpha^2/(1-\alpha)} \text{ under (1).}$$

Consequently, it is more likely that the forest still exists at some future date if the good is close to being a traditional good - in the sense that the direct value D is large while the conservation value E is small (both relative to the consumption value C). A large E means that the equilibrium price for conservation is high, which in turn implies both that the buyer is less likely to buy and that the seller is more likely to cut.

The effect of the equilibrium price also explains why the good is less likely to be conserved if the seller's bargaining power is high. 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 good is eventually bought and conserved with probability one.

[16] To see the following corollary, note that the probability that the forest has been bought before the end of period t is:

$$b+(1-b)(1-c)\,b+...+[(1-c)(1-b)]^{t-1}\,b=\frac{b\left(1-[(1-b)(1-c)]^t\right)}{1-(1-b)(1-c)}.$$

When we substitute for the equilibrium b and c and let $t \to \infty$, this becomes:

$$\frac{E/(P-D)-\delta}{E/(P-D)-\delta+\delta P/C-1}=\frac{E-\delta\,[(1-\alpha)(C-D)+\alpha E]}{E+[\delta\alpha\,(D+E-C)/C-1]\,[(1-\alpha)(C-D)+\alpha E]},$$

when we substitute for P from (1). The probability decreases in δ because of B's vanishing first-mover advantage; it is thus more interesting to look at the limit when $\delta \to 1$, giving the corollary. Another way of seeing the corollary is by inspecting the equilibrium of the continuous-time model in Section 5.1.

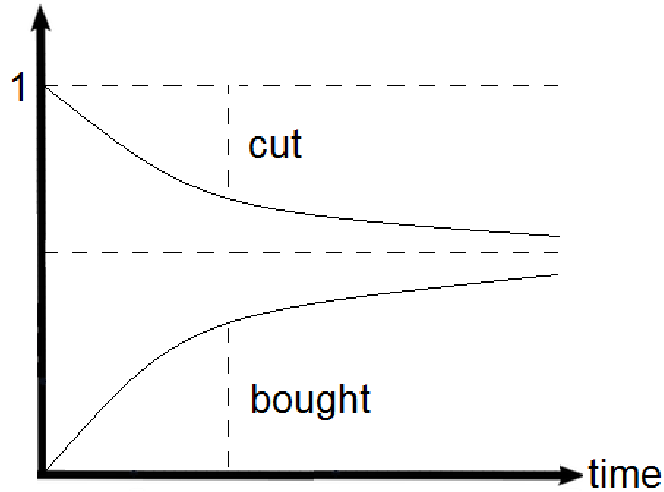

Figure 3: *The probabilities that the forest has been cut or purchased as functions of time*

It is also straightforward to let parameters vary over time.[17]

2.5 Payoffs and Investments

At the start of the game, the equilibrium payoff for the buyer, V_B, is pinned down by the fact that buying is always a best response. Thus, $V_B = D - P$. For a traditional good such that $P < D$, or if $P < C/\delta$, we have learned that the buyer purchases with probability one, so that the seller's equilibrium payoff at the start of the game is $V_S = P$. The sum of these payoffs is simply D, independent of P or, given (1), of α.

The more interesting situation with conservation goods arises when $C/\delta \leq P$. In equilibrium, the seller is indifferent between cutting and waiting for her discounted equilibrium payoff, δV_S. Thus,

$$V_B = D - P; \tag{3}$$

$$V_S = \frac{C}{\delta}. \tag{4}$$

[17] If parameters varied over time, this should be reflected by using subscript t for period t, for example. Then, S and B would be indifferent (and thus willing to randomize) at their decision nodes when, respectively:

$$b_{t+1} = \frac{C_t}{P_{t+1} - C_t}\left(\frac{1-\delta}{\delta}\right) \text{ and } c_t = \frac{(1-\delta)(P_t - D_t)}{E_t - \delta(P_t - D_t)}.$$

The Nash bargaining solution for P_t would be given by $P_t = (1-\alpha) C_t + \alpha (D_t + E_t)$.

Interestingly, the sum of payoffs declines in the equilibrium price - or in the seller's bargaining power, α. This is in contrast to the case for the traditional good. For conservation goods, a low price implies that the probability (or the level) of trade is larger. It would thus be socially efficient that B had most of the bargaining power.

Given these equilibrium payoffs, we can easily study the players' incentives to influence any of the parameters in the model - if they could. Although such influence is not present in the model, it follows straightforwardly that S would have no incentive to raise B's value of conservation at the beginning of the game. For a given P, this would have made it more attractive for B to contact S unless, as would have happened in equilibrium, S were less likely to cut. Thus, S's payoff would stay unchanged. Even when P increases following a larger E (as in (1)), S would not benefit since B buys less if P is high (Proposition 1). Also this result is in stark contrast to the case for traditional goods.[18]

We may also consider the seller's incentive to improve her outside option, i.e., the value of the timber or the land, C. In reality, S can raise C by investing in roads and logging capacity or by negotiating market access with trading partners. From (4), we know that $\partial V_S/\partial C = 1/\delta > 1$. Thus, S's incentive to raise the value of cutting, C, is *larger* than it would have been if conservation had not been an issue (then, $\partial V_S/\partial C = 1$). The intuition is that if C increases, B must buy with a larger probability. This effect is very beneficial for S and it strongly motivates her to invest in C.

COROLLARY 3. *Suppose $C/\delta \leq P$. The seller has no incentive to increase the value of conservation, E, but strong incentives to raise the value of cutting, C.*

3 The Rental Market

3.1 Stage Game

In a rental or leasing market for conservation, the buyer pays the current owner to conserve the good for a given length of time. There are several reasons to analyze this market: (i)

[18] For traditional goods (when $P < D$, or if $P < C/\delta$), the buyer buys with probability one and S does have an incentive to raise both D and E if S can then expect a higher price (1). If $\alpha < 1$, the buyer has some of the bargaining power and the price does not rise one-to-one when S enhances the value of the good: this is the familiar holdup problem, which leads to investments which are suboptimally low but still positive. In contrast, for conservation goods (when $P > \max\{D, C/\delta\}$), S has absolutely *no* incentive to raise B's valuation, *no matter* how the bargaining power is allocated.

the sales market, analyzed above, proved to be very inefficient; (ii) existing REDD-contracts specify payments conditional on annual avoided deforestation,[19] and they are thus more similar to leasing arrangements than to sales; (iii) it may be very costly for a buyer to protect a forest that is geographically far away from illegal logging; and (iv) a buyer may fear that the seller will attempt to renationalize the forest after a sale.

Arguments (iii) and (iv) suggest that buying may be a costly conservation method. This cost can be captured by assuming that $D < 0$ in B's payoff following a purchase. In fact, the best interpretation of $-D$ is that it represents the present-discounted cost for B when protecting the forest forever against illegal logging or S's attempt to renationalize it. Naturally, this cost is not paid when B leases the forest, since S is then herself interested in protecting the forest so that it can also be rented in the future. The saved protection (or maintenance cost) is exactly the benefit of renting typically assumed and discussed in the Introduction (as well as in Levy and Sarnat, 1994). The model can easily be reformulated to capture a protection cost for the seller as well (see footnote 23).

Figure 4 illustrates that the stage game is otherwise quite similar to the one for the sales market. At the beginning of a period, B first decides whether to contact S, anticipating that he then will be able to rent conservation at the (equilibrium or exogenous) price p. If B rents, the rental price p is this period's payoff to S. If B does not rent, S decides whether to cut or conserve. If S conserves, payoffs are zero in this period. Cutting, however, ends the game and gives the payoff C to S and the payoff $-E$ to B, just as before. Since D is irrelevant in the rental market, the good is a conservation good if $C < E$.

The one-period version of the rental game is thus very similar to the one-period version of the sales game, and the two are identical if $D = 0$. I here let $b \in [0, 1]$ denote the probability that B rents, while $c \in [0, 1]$ is the probability that S cuts at her decision node. For every price strictly between C and E, the unique subgame-perfect equilibrium is $b = c = 1$. The sum of equilibrium payoffs is strictly higher in the rental market than in the sales market if $D < 0$, but strictly lower if $D > 0$.

[19] Norway's REDD+ agreements with Brazil, Guyana, Indonesia, Tanzania and Mexico can be found online: http://www.regjeringen.no/en/dep/md/. The United Nations' REDD program is described here: http://www.un-redd.org/.

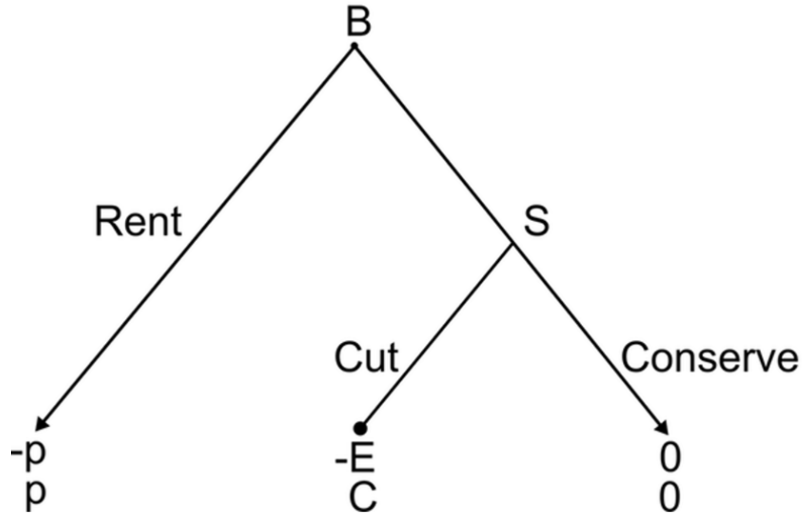

Figure 4: *The stage game in the rental market*

3.2 The Dynamic Rental Game and Equilibrium

As justified above, I assume (1) the buyer does not enjoy D in the rental market and (2) a rental contract is temporary and future contracts cannot be negotiated in advance.[20] While Section 5.1 permits rental contracts of any length, this section simplifies by considering only one-period rental contracts. So, if B rents, S agrees to conserve and to protect the good for one period but thereafter, the players enter the next period with the identical stage game. Thus, only cutting ends the game. If one or both of assumptions (1)-(2) are relaxed, the comparison between the two markets becomes trivial, as discussed at the end of this section.

Just as before, there are multiple subgame-perfect equilibria, but the set of renegotiation-proof equilibria, the set of Markov-perfect equilibria, and the set of stationary equilibria essentially coincide and permit a unique equilibrium. Section 4.3 explains this in detail; this section is again taking the shortcut of simply focusing on stationary equilibria. After all, the subgames at the beginning of different periods are always identical as long as the forest still exists, and the date as well as the history is "payoff-irrelevant" (Section 4.3). The equilibrium strategies can thus again be summarized by the stationary pair (b, c).

The rental price can, for present purposes, be exogenously given or endogenously deter-

[20] Both these differences between leasing and buying are well recognized and standard to assume; see the textbook by Levy and Sarnat (1994:657-76). The temporal aspect of the leasing contract is also reflected in the discussion of Tirole (1998:81-4).

mined as described in Sections 4.1-4.2. In either case, the interesting and reasonable case is where the present-discounted cost of renting forever, $p/(1-\delta)$, lies between C and E. If $p/(1-\delta) \leq C$, it is a best response for S to cut and not accept a leasing contract. If $p/(1-\delta) \geq E$, it is a best response for B to not rent.

PROPOSITION 2. *Suppose $\delta > C/E$.*[21] *The strategies (b, c) constitute an equilibrium if and only if:*

$$\begin{array}{llllll} \text{(i)} & b = 1 & \textit{and} & c = 1 & \textit{if} & \frac{p}{1-\delta} \in \left[C, \frac{C}{\delta}\right); \\ \text{(ii)} & b = 1 & \textit{and} & c \in \left[\frac{p(1-\delta)}{E(1-\delta)-\delta p}, 1\right] & \textit{if} & \frac{p}{1-\delta} = \frac{C}{\delta}; \\ \text{(iii)} & b = \frac{C}{p}\left(\frac{1-\delta}{\delta}\right) & \textit{and} & c = \frac{p(1-\delta)}{E(1-\delta)-\delta p} & \textit{if} & \frac{p}{1-\delta} \in \left(\frac{C}{\delta}, E\right); \\ \text{(iv)} & b \in \left[0, \frac{C}{p}\left(\frac{1-\delta}{\delta}\right)\right] & \textit{and} & c = 1 & \textit{if} & \frac{p}{1-\delta} = E. \end{array} \quad (5)$$

The equilibrium is analogous to that of the sales market. If $p \leq C(1-\delta)/\delta$, the seller prefers cutting to renting forever after, and the buyer must and will rent immediately and always with probability one. In contrast, if $p > C(1-\delta)/\delta$, the seller prefers conservation if she expects that the buyer will rent; but if S conserves, B does not want to rent. So, if $p/(1-\delta) \in (C/\delta, E)$, which is the reasonable case when is δ large, then the unique equilibrium is in mixed strategies. In each period, the buyer rents with a probability which is such that S is just indifferent between cutting or not, and S cuts at a rate which makes B just willing to rent in a given period.[22]

The comparative static is similar to the sales market. For example, if the price for conservation is high, B is willing to rent only if S cuts at a faster rate (so c increases in p), while S is willing to cut only if B rents with a lower probability (so b declines in p). If b and c were drawn as functions of p, the figure would be quite similar to Figure 2, above.

Corollaries 1 and 3 extend to the rental market. Just as for the sales market, b can be interpreted as the (expected) fraction of the remaining forest that is rented in a given period, while c can be interpreted as the (expected) fraction of the remaining forest, not

[21] If $\delta < C/E$, the unique equilibrium is trivially $b = c = 1$, since there is no p that B is willing to pay which makes S willing to conserve at the cutting stage.

[22] Note that there is no need to assume that S can precommit when promising to conserve the forest in cases (ii) and (iii). The seller is indifferent when considering protection of the good at the cutting stage, whether or not B has rented the good for this period. Thus, S does not need to commit and B's payment does not need to be conditioned on actual conservation. However, if S were assumed to protect the good with the same probability whether or not the good would be rented, then there would be no value in a rental arrangement and B would never rent.

already under contract, that is cut at the cutting stage. This way, the strategies above can be purified.

If S could invest in order to enhance B's conservation value, as in Section 2.5, she would never do so (in cases (ii)-(iii)). The seller's equilibrium continuation value is given by C/δ, which is independent of E and even p. This also implies, as in the sales market, that S has a stronger incentive to increase the value of cutting, C, than she would have had if conservation were not an issue.

Note that Corollary 2 does not hold for the rental market. Since only cutting ends the game, the probability that the good is conserved approaches zero as time goes by.

3.3 Lease or Buy Conservation?

Despite the similarities, the rental market and the sales market are not equivalent. On the one hand, the rental market has the disadvantage that the game never ends before S cuts. On the other, in the rental market, the seller is protecting the good and not the buyer. Thus, if $D < 0$, renting every period would be a first-best outcome, while a sale implies a loss. In fact, a sales market exists (for some P) only if $E > C + (-D)$, while the rental market exists (for some p) whenever $E > C$.

To make positive predictions regarding the choice between sales and rental contracts, consider first the sales market. If the buyer has contacted the seller, the two of them may consider a one-period rental contract as an alternative to a sale. It is reasonable that they will sign a rental contract if and only if there exists *some* rental price such that both B and S are better off by signing such a contract rather than signing the sales contract. The rental contract lasts one period only, and in the following period, either (a) B may consider renting again at some (equilibrium) price, or (b) B and S may revert to the equilibrium in the sales market. Regardless of whether the future is expected to be (a) or (b), the following proposition describes the condition for when a rental contract exists which Pareto-dominates selling at the negotiation stage.

PROPOSITION 3. (i) *Consider an equilibrium in the sales market. There exists a rental contract which both B and S strictly prefer to selling if and only if B's protection cost is* *high:*

$$(-D) > \max\left\{0, \frac{\delta P - C}{1-\delta}\right\}. \tag{6}$$

(ii) *Consider an equilibrium in the rental market. There is no sales contract which both B and S weakly prefer if and only if B's protection cost is high:*

$$(-D) > \max\left\{0, \frac{\delta p}{1-\delta} - C\right\}. \tag{7}$$

While a sale would eliminate the possibility of future cutting, renting has an advantage if it is costly for the buyer to protect the forest after a purchase, i.e., if $-D > 0$ is sufficiently large. The model therefore predicts that conservation of areas far away will be leased, while local conservation, perhaps within the buyer's own country, will be bought.

A sale is also more attractive if the seller's benefit from cutting, C, is small, since B is then less likely to rent again, as explained above, which makes it beneficial to trade now to end the game.

Finally, note that a sale is also more likely if the equilibrium sale price is large! If B is ready to buy at a high P, S accepts a leasing contract instead only if p is high. But with high conservation prices, the equilibrium rate of cutting is large. Rather than risk future cutting in the leasing market, S and B are better off trading once and for all.

If the prices are given by the generalized Nash bargaining solution, such that the sales price is (1), then Section 4.1 shows that (6)-(7) coincide and become:

$$(-D) > \max\left\{0, \frac{\delta\alpha E}{1-\delta+\delta\alpha} - C\right\}. \tag{8}$$

Figure 5 illustrates the parameter-set under which "rent" is preferred by B and S. Condition (8) is illustrated as the kinked downward-sloping dashed line. Thus, in the area "rent" (or "buy"), both markets exist but the rental (or sales) market is strictly better. In the area "RENT" (or "BUY"), only the rental (sales) market exists.

We can introduce a maintenance or protection cost for the seller as well as for the buyer. It is easy to show that, in that case, the analysis does not need to be modified at all, since C can be interpreted as the value of cutting *plus* the seller's saved protection cost, if just D is interpreted as the *difference* between the players' protection costs.[23]

[23] To be precise, let G_B be B's present discounted cost of forever protecting the forest, while G_S is the

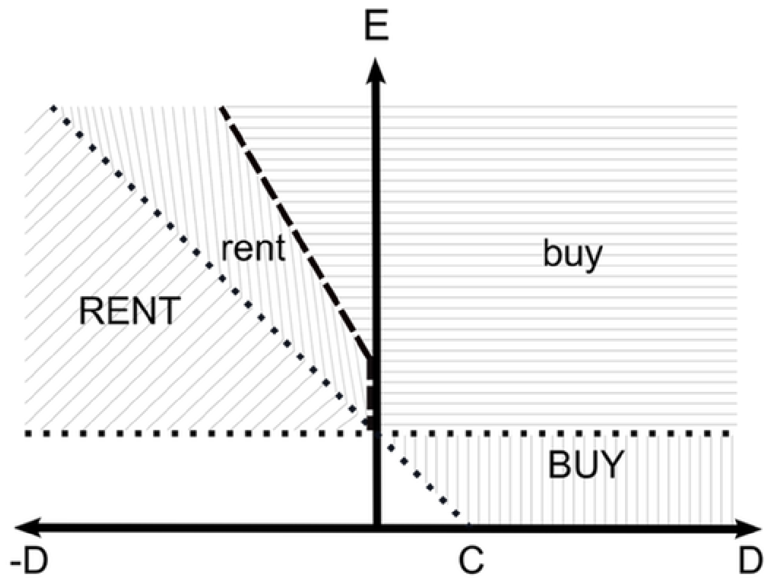

Figure 5: *Leasing is better than buying if* $-D > 0$ *is large*

It is also straightforward to allow for a T-period leasing agreement, where T may be larger than 1. Intuitively, the larger is T, the better is leasing relative to buying.[24]

As a concluding remark, let us reconsider the two assumptions mentioned at the start of

analogous cost for S. Denote by $\underline{C}$ the seller's consumption value. With status-quo payoffs normalized to zero, S gains $\underline{C} + G_S$ if she cuts. All the above results and payoffs in the sales market stay unchanged with the interpretations:

$$\begin{aligned} C &\equiv \underline{C} + G_S, \\ D &\equiv G_S - G_B, \text{ and} \\ P &\equiv \underline{P} + G_S, \end{aligned}$$

where $\underline{P}$ is the sales price. Note that it follows that $D < C$ (when $\underline{C} > 0$ and $G_B > 0$), and that $D < 0$ if $G_S < G_B$. When the price $\underline{P}$ is negotiated, S requires at least $\underline{C}$ (since she receives G_S whether she sells or cuts) while B is willing to pay at most $E - G_B$. When we let the generalized Nash bargaining solution characterize the sales price $\underline{P}$, where α is S's share of the bargaining surplus, it follows that:

$$\underline{P} = (1-\alpha)\,\underline{C} + \alpha\,(E - G_B) \Rightarrow P = \underline{P} + G_S = (1-\alpha)\,C + \alpha\,(E + D)\,,$$

exactly as before. The rental market is also unchanged. An earlier version of this paper discusses all this in detail.

[24]Section 5.1 allows for an arbitrary length of leasing constracts when time is continuous. With discrete time and a T-period leasing arrangement, then condition (6), for example, will be replaced by (as I show in an earlier version of this paper):

$$(-D) > \max\left\{0, \frac{\delta^T}{1-\delta^T}\left(P - \frac{C}{\delta}\right)\right\}.$$

Section 3.2. If we relax assumption (2) by allowing B and S to sign a rental agreement that lasts forever, then the only difference is that B enjoys D following a purchase but not when he is renting; as a result, buying is always preferred when $D > 0$ but never when $D < 0$. It is also straightforward to allow for a T-period leasing agreement, where T may be larger than 1. Intuitively, the larger is T, the better is leasing relative to buying.[25]

If we instead relax assumption (1) such that D (or the per-period equivalent $D(1-\delta)$) is also experienced in a renting agreement, then renting will never take place, since a sale more effectively eliminates the future probability for an inefficient cutting.

If both assumptions (1)-(2) are relaxed, the two markets are equivalent.

4 Robustness: Prices, Negotiations, and Equilibria

The above analysis holds regardless of the determinants of the price. The inefficiency, and the equilibrium cutting, always arises as long as (a) the actual price is strictly higher than the seller's minimal requirement and (b) trade is voluntary. The mechanism above were demonstrated more generally when the price-determination were a 'black box', since there are multiple ways of endogenizing the price and still satisfy (a)-(b). The first subsection below states two assumptions which permit a unique equilibrium price which depends on the model's parameters in an intuitive way. Both assumptions are replaced in the second subsection, where I find multiple equilibrium prices.

4.1 The (Nash) Bargaining Solution

The simplest, and perhaps most intuitive way of endogenizing the prize is as already discussed in Section 2.1. Following that line of reasoning, in this subsection I assume that, if B contacts S, then the bargaining outcome is efficient and (I) S captures the fraction $\alpha \in [0,1]$ of the bargaining surplus while (II) the threat point is that S cuts Part (I) is consistent with

[25] Section 5.1 allows for an arbitrary length of leasing constracts when time is continuous. With discrete time and a T-period leasing arrangement, then condition (6), for example, will be replaced by (as I show in an earlier version of this paper):

$$(-D) > \max\left\{0, \frac{\delta^T}{1-\delta^T}\left(P - \frac{C}{\delta}\right)\right\}.$$

the generalized Nash bargaining solution, but it is also the outcome of a noncooperative bargaining game where S makes the final offer with probability α.[26] Part (II) suggests that if B and S do negotiate but (unexpectedly) fail to reach an agreement, then S cuts. Note that the equilibrium is still stationary in that the strategies are independent of time itself (even though strategies depend on whether bargaining has recently failed).

It is easy to see that the equilibrium P is as characterized by (1) and Proposition 1 continues to hold for the sales market.

PROPOSITION 4. *Let $\alpha \in [0,1]$ be S's bargaining power index.*
(i) *There is a unique equilibrium sales price, given by (1): $P = (1-\alpha)\,C + \alpha\,(D+E)$.*
(ii) *There is a unique equilibrium rental price:*

$$\frac{p}{1-\delta} = \left\{ \begin{array}{ccc} (1-\alpha)\,C + \alpha E & \text{if} \quad \alpha < \left(\frac{1-\delta}{\delta}\right)\frac{C}{E-C} & \text{(i)} \\ \frac{\alpha}{1-\delta+\delta\alpha}E & \text{if} \quad \alpha \geq \left(\frac{1-\delta}{\delta}\right)\frac{C}{E-C} & \text{(ii)} \end{array} \right\}. \tag{9}$$

The results continue to hold if the threat point instead is that the transaction will take place in the alternative market. In the rental market, for example, the threat point may be that B instead buys at price (1). With this threat point, the equilibrium rental price is unchanged and still equal to (9).[27]

Intuitively, the price increases in the seller's bargaining power α and the buyer's value of conservation E. In the sales market, the price is simply a weighted average of the two players' valuations. This is also the case in the rental market if α and δ are relatively small.[28] With endogenous prices, we can describe the equilibria of Propositions 1 and 2 as functions of the allocation of bargaining power:

[26] To see this, consider a finite (but not necessarily) alternating-offer bargaining game with negligible discounting between each offer, and where S makes the final offer (which would be $P = D + E$) with probability α while B makes the final offer (which would be $P = C$) with probability $1-\alpha$. Solving the game by backwards induction trivially gives that the first offer (regardless of the identity of the proposer) satisfies (1). It is also well-known that the generalized Nash bargaining solution "is identical to the (limiting) bargaining outcome that is generated by the basic alternating-offers model" (Muthoo, 1999, p. 52, drawing on Binmore, 1987). Any difference in discount rates would then influence the allocation of bargaining power.

[27] This claim follows from the proof of Proposition 4. The intuition for this equivalence is that the surplus from selling, relative to cutting, is distributed by the same sharing rule (α) as when sharing the surplus from renting.

[28] Otherwise, however, p is independent of C. The intuition is as follows. Note that we can rewrite the second inequality in (9) as $C/\delta \leq p/(1-\delta)$, which implies that the seller is always indifferent at the cutting stage and her continuation value is the same (C/δ), whether or not she promises to conserve in this period. Thus, her bargaining surplus is simply p, independent of C. This explains why C does not influence p in this case. A somewhat larger C is reflected in the larger b, but not in a larger price.

Corollary 4. *Combined, Propositions 1 and 4 imply that the sales market equilibria are:*

$$\begin{array}{llll}
\text{(i)} & b=1 & \text{and } c=1 & \text{if } \alpha<\frac{1-\delta}{\delta}\frac{C}{D+E-C}; \\
\text{(ii)} & b=1 & \text{and } c\in\left[\frac{(1-\delta)[\alpha+(1-\alpha)(C-D)/E]}{1-\delta[\alpha+(1-\alpha)(C-D)/E]},1\right] & \text{if } \alpha=\frac{1-\delta}{\delta}\frac{C}{D+E-C}; \\
\text{(iii)} & b=\frac{C}{D+E-C}\left(\frac{1/\delta-1}{\alpha}\right) & \text{and } c=\frac{(1-\delta)[\alpha+(1-\alpha)(C-D)/E]}{1-\delta[\alpha+(1-\alpha)(C-D)/E]} & \text{if } \alpha\in\left(\frac{1-\delta}{\delta}\frac{C}{D+E-C},1\right); \\
\text{(iv)} & b\in\left[0,\frac{C}{D+E-C}\left(\frac{1}{\delta}-1\right)\right] & \text{and } c=1 & \text{if } \alpha=1.
\end{array}$$

Corollary 5. *Combined, Propositions 2 and 4 imply that the rental market equilibria are:*

$$\begin{array}{llll}
\text{(i)} & b=1 & \text{and } c=1 & \text{if } \alpha<\left(\frac{1-\delta}{\delta}\right)\frac{C}{E-C}; \\
\text{(ii)} & b=1 & \text{and } c\in[\alpha,1] & \text{if } \alpha=\left(\frac{1-\delta}{\delta}\right)\frac{C}{E-C}; \\
\text{(iii)} & b=\frac{C}{E}\left(1+\frac{1/\delta-1}{\alpha}\right) & \text{and } c=\alpha & \text{if } \alpha\in\left(\left(\frac{1-\delta}{\delta}\right)\frac{C}{E-C},1\right); \\
\text{(iv)} & b\in\left[0,\frac{C}{\delta E}\right] & \text{and } c=1 & \text{if } \alpha=1.
\end{array}$$

For both markets, case (iii) is most interesting (and most plausible, if δ is large). The comparative static is then similar for the two markets: b increases in C but decreases in E, δ, and α, while c increases in α.[29] Both markets for conservation are thus more efficient if the player preferring conservation has most of the bargaining power.

By substituting for the equilibrium prices into Proposition 3, we get a better understanding of when renting dominates buying.

Corollary 6. *Combined, Propositions 3 and 4 imply that the two conditions for when renting is preferred (6-7) coincide and become (8).*

It should not surprise that the two conditions from Proposition 3 coincide: the threat point and the division of surplus are, by assumption, the same whether B and S negotiate P or p, so both players prefer the contract maximizing total surplus.

The best contract is thus a renting contract only if E and α are quite small. If instead the value of conservation (E) or the seller's bargaining power (α) is large, then the equilibrium rental price is high and it is then quite likely that the future market outcome under renting will be inefficient and involve cutting. It is better, then, to trade once and for all, to end the game.[30]

[29] However, in the rental market, c does not depend on any other parameter than α. If E were large, for example, the buyer would be more tempted to buy for a fixed p; this would require a smaller c, in line with (5). But when p is linear in E, as in Proposition 4(ii) and as explained in the previous footnote, then the buyer does not become more tempted to buy when E is large, so that to keep B indifferent, c must stay invariant to E.

[30] Note that as $\delta \to 1$, the area where renting is preferable converges to the area "RENT" where the sales

4.2 Proposing a Price

This subsection modifies the first assumption above by assuming that (I') if the buyer contacts the seller, then the seller has all the bargaining power and can make a take-it-or-leave-it offer regarding the price. I also relax the second assumption by instead assuming that (II') if the buyer rejects, the two players return to the stationary equilibrium (characterizing b and c) just as if no negotiations had taken place. Otherwise, the game is the same as before: in each period, B decides whether to contact S and, if he doesn't, S decides whether to cut. Thus, B must agree to negotiate (by showing up at the bargaining table, for example) before S can propose a price.[31]

The buyer's stationary strategy describes both the probability b for contacting S and the highest price P which he is willing to accept. The seller's strategy describes both the probability of cutting c and the proposed price once B contacts S. Since S prefers to propose the highest price which B is willing to accept, P, an equilibrium can be summarized simply as $(b, c; P)$.

It is easy to see that the anticipation of price P can be self-fulfilling, leading to multiple equilibria. Specifically, if the players believe the equilibrium price is $P \in (C/\delta, D + E)$, we know from Proposition 1 that $b \in (0, 1)$ so that the buyer is just indifferent between buying at P and staying passive. Thus, if B does indeed contact S, S knows that B will accept at most the price P, so S proposes this exact price.

PROPOSITION 5. *Suppose S proposes the price.*
(i) *In the sales market, the triplet $(b, c; P)$ represents an equilibrium if and only if*

$$\begin{array}{llll} P \in \left[\frac{C}{\delta}, D+E\right), & b = \frac{C}{P-C}\left(\frac{1-\delta}{\delta}\right), & \textit{and} & c = \frac{(1-\delta)(P-D)}{E-\delta(P-D)} \quad \text{or} \\ P = D+E, & b \in \left[0, \frac{C}{P-C}\left(\frac{1-\delta}{\delta}\right)\right], & \textit{and} & c = 1. \end{array}$$

(ii) *In the rental market, the triplet $(b, c; p)$ represents an equilibrium if and only if*

$$\begin{array}{llll} \frac{p}{1-\delta} \in \left[\frac{C}{\delta}, E\right), & b = \frac{C}{p}\left(\frac{1-\delta}{\delta}\right), & \textit{and} & c = \frac{p(1-\delta)}{E(1-\delta)-\delta p} \quad \textit{or} \\ \frac{p}{1-\delta} = E, & b \in \left[0, \frac{C}{p}\left(\frac{1-\delta}{\delta}\right)\right] & \textit{and} & c = 1. \end{array}$$

market is nonexistent. The explanation is that as each period becomes very short, the cost of risking cutting in each of these periods becomes arbitrarily large. This suggests that one-period contracts are unreasonable when $\delta \to 1$, which motivates the extension to longer leasing arrangements (Section 5.1).

[31] Otherwise, S would have an incentive to announce a low price to attract B to the bargaining table; however, such an announcement would have no impact if S could renege once B were sitting at the bargaining table.

Part (i) states that endogenizing P (according to I'-II') does not pin down a unique price, and the set of equilibria is a large and strict subset of those described by Proposition 1. However, we can rule out the lowest prices considered by Proposition 1, where $P < C/\delta$, since S's best response would then be $c = 1$, implying that S could charge $P = D + E$; a contradiction. Furthermore, we cannot have $c > (1-\delta)(P-D)/[E-\delta(P-D)]$ if $P = C/\delta$, as was permitted by Proposition 1(ii), since B would then strictly prefer to buy and, hence, accept to buy at a slightly larger price.

Part (ii) is similarly saying that there are multiple equilibria for the rental price and the set of equilibria is a strict subset of those described by Proposition 2. The intuition is analogous to Part (i). For each market, note that the only equilibrium in pure strategies is that conservation ends immediately:

Corollary 7. (i) *There is exactly one pure-strategy equilibrium in the sales market:*

$$P = D + E, b = 0, c = 1.$$

(i) *There is exactly one pure-strategy equilibrium in the rental market:*

$$\frac{p}{1-\delta} = E, b = 0, c = 1.$$

Of course, all these results hinge on the bargaining game as described by (I')-(II'). If we continue to assume (II') but relax (I'), such that both players can expect a positive fraction of the bargaining surplus, then we cannot have equilibria $P > C/\delta$ where B is indifferent while S strictly benefits from trade. Instead, in this situation, there is a unique equilibrium were $P = C/\delta$ and $b = 1$, such that the forest will be conserved immediately with probability one.[32] The purpose of this section is thus *not* that $P \in (C/\delta, D+E)$ must hold independent of the bargaining game, but that this is possible (for some games) as well as intuitive.

4.3 Equilibria, Refinements, and Renegotiation Proofness

This subsection is intended to describe more precisely the set of strategies, equilibria, and the reasons why the equilibria emphasized above are relevant. In short, I show that as long

[32] The equilibrium level of c will then depend on the allocation of bargaining power. If, for example, we apply the generalized Nash bargaining solution, where $\alpha \in [0,1]$ represents the fraction of the bargaining surplus captured by S, then

$$P - C = \alpha[P - C + D - P + cE - \delta(1-c)(D-P)] \Rightarrow c = \frac{C - \alpha\delta D}{E + \delta D - C}\frac{1-\delta}{\alpha\delta}.$$

as we require the equilibria to be renegotiation-proof or, alternatively, Markov-perfect, then they must take the form described by the propositions above.

Consider first the sales market. The price P can be endogenous as in Section 4, but I here follow Sections 2-3 by treating the price as exogenous. In every period t, B first chooses an *action* $a_t^B \in \{0,1\}$ and, if $a_t^B = 0$, then S chooses an action $a_t^S \in \{0,1\}$. A history at the start of period t is a sequence of actions $\{a_1^B, a_1^S, ..., a_{t-1}^B\}$ or $\{a_1^B, a_1^S, ..., a_{t-1}^B, a_{t-1}^S\}$.[33] For each player, a *strategy* specifies a randomization over possible actions after each possible history. This game is a quitting game with alternating moves which stops as soon as one player has chosen action 1. Thus, an action is possible at t only after a history of zero's, so a player's strategy at t is necessarily conditioned on the unique history in which no player has stopped. Therefore, the strategies at the beginning of period t is simply a pair $s^t = (b^t, c^t)$ where $b^t = (b_t, b_{t+1}, ...)$ and $c^t = (c_t, c_{t+1}, ...)$; each $b_\tau \in [0,1]$ denotes B's probability for choosing $a_\tau^B = 1$ while each $c_\tau \in [0,1]$ denotes S's probability for choosing $a_\tau^S = 1$ for every integer $\tau \geq t$. Similarly, $s_+^t = (c^t, b^{t+1})$ is the strategies at the cutting stage in period t. The strategy pair s^t is a Nash equilibrium if b^t is a best response to c^t and c^t is a best response to b^t. Furthermore, s^t is subgame-perfect if s^τ and s_+^τ are Nash equilibria for every $\tau \geq t$.

There are many subgame-perfect equilibria in this game. Some of them are in pure strategies and some always lead to conservation. If $P < D$, then B's unique best response would be $b_t = 1$. If $P < C/\delta$, then $c_t = 1$ and thus $b_t = 1$ are strictly best responses for every t, and thus a unique sub-game perfect equilibrium. We will therefore consider again the more interesting case where $P > C/\delta$ and $P > D$.

Example. If $P > C/\delta$, we can always find an integer $\Delta > 1$ such that:

$$\delta^\Delta P \leq C < \delta^{\Delta-1} P.$$

The first inequality means that S prefers cutting today to selling in Δ periods, while the second inequality means that S prefers selling in $\Delta - 1$ periods to cutting. The following is thus a subgame-perfect equilibrium in pure strategies: $b_t = c_t = 1$ when $t \in \{1, 1+\Delta, 1+2\Delta, ..\}$, while $b_t = c_t = 0$ otherwise. The outcome is that B buys immediately, since S will otherwise

[33] Although each decision maker is free to randomize over the two actions, the history does not include past randomization probabilities when there is no public randomization device.

cut immediately. If S deviates, B will not buy in the following period since B knows that it is thereafter in the interest of S to wait for trade in $\Delta - 1$ periods.

Unfortunately, the strategies in the Example are neither stationary nor Markov-perfect. Markov-perfect equilibria require that strategies be contingent only on "payoff-relevant" partitions of histories (Maskin and Tirole, 2001). Here, the only payoff-relevant aspect to any history is whether or not the game has terminated. The time itself is not payoff-relevant: if one player's strategy is not contingent on time, then the other player cannot benefit from such contingency either.[34] It follows that in the game of this paper, the Markov-perfect equilibria must be in stationary strategies. The strategies in the above Example are not stationary, so they cannot be Markov-perfect.

The equilibrium in the Example is not renegotiation-proof, either. At the interim stage in period 1 (i.e., S is ready to cut because B did not buy), then both players prefer to renegotiate or redefine the time (to period 2, for example). If both players can strictly benefit by simply coordinating on another pair of equilibrium strategies, then the initial equilibrium is clearly vulnerable. Thus, one may want to restrict attention to equilibria which are robust to such simple re-coordination - particularly when one is interested in the most efficient equilibria.

The rest of this subsection shows that by adhering to standard notions of renegotiation-proofness,[35] the equilibrium must converge to those described by Proposition 1 (for the sales market) and Proposition 2 (for the rental market) after at most two periods. In other words, if one insists on renegotiation-proof equilibria and believes that the game started more than two periods ago, then the equilibrium must be unique and exactly as described in Sections 2-3.

As noted, there are two different types of subgames, depending on whether B or S is the next player to act. Two subgames are called identical if the next player to act is the same in both subgames.

Definition. A subgame-perfect equilibrium (s^t or s^t_+) is *weakly renegotiation-proof* if the

[34] I here follow the reasoning of Maskin and Tirole (2001:202-3), but there exist other interpretations of "Markov-perfect equilibria" which permit non-stationarity (Duffie et al., 1994).

[35] Here I adopt the definitions for infinitely repeated games by Farrell and Maskin (1989), also presented in the textbook by Mailath and Samuelson (2006:134-8). However, there are several different definitions of renegotiation-proofness and, needless to say, the results may or may not hold if alternative definitions are used.

continuation payoff profiles at any pair of identical subgames are not strictly ranked.

In other words, there is no time at which both players would strictly benefit from following the strategies specified for a different time (where the identity of the next mover is preserved). Let S^w denote the set of weakly renegotiation-proof equilibria where B is the next player to act. Note that S^w must be independent of time. The set S^w_+ is defined analogously.

Definition. A subgame-perfect equilibrium $s^t \in S^w$ or $s^t_+ \in S^w_+$ is *strongly renegotiation proof* if no continuation payoff profile is strictly Pareto-dominated by the continuation payoff profile of another $s' \in S^w$ or $s'_+ \in S^w_+$.

Let $S^s \subseteq S^w$ and $S^s_+ \subseteq S^w_+$ denote the set of strongly renegotiation-proof equilibria. It turns out that every equilibrium which is (weakly or strongly) renegotiation-proof coincides with the one described by Proposition 1, at least after the first two periods. The proof in the Appendix explains and fully characterizes the set of all renegotiation-proof equilibria.

Proposition 6. (i) *Consider the sales market and suppose that $P > C/\delta$. We then have $S^w = S^s$ and $S^w_+ = S^s_+$. Furthermore, if $s \in S^w = S^s$ or $s_+ \in S^w_+ = S^s_+$, then*

$$b_t = b \text{ and } c_t = c \; \forall t > 2, \tag{10}$$

where b and c are as described by Proposition 1.
(ii) *Consider the rental market and suppose that $p/(1-\delta) > C/\delta$. We then have $S^w = S^s$ and $S^w_+ = S^s_+$. Furthermore, if $s \in S^w = S^s$ or $s_+ \in S^w_+ = S^s_+$, then*

$$b_t = b \text{ and } c_t = c \; \forall t > 2,$$

where b and c are as described by Proposition 2.

Part (ii) says that the reasoning above also holds for the rental market. The main difference is that, in the rental market, the set of relevant histories at the start of period t must satisfy $a^S_\tau = 0$, $\tau < t$, but not necessarily $a^B_\tau = 0$. Thus, the strategies can be contingent on whether (and when) B has rented in the past. Such contingencies, however, do not have much bite when the players can renegotiate: there can still be no pair of histories such that both players strictly benefit from following the strategies described for another possible subgame.

5 Extensions: Multiple Buyers and Sellers

5.1 Continuous Time

In this subsection, the results of Propositions 1-4 are restated for the case with continuous time. This will be useful when we next allow for multiple buyers and sellers. The common discount rate is r, while $\widetilde{b}$ and $\widetilde{c}$ denote the *Poisson rates* at which B contacts S and S cuts, respectively, if the game has not yet ended. If the rental contract can be of any length up to T, where T is an exogenous upper threshold (perhaps limited by political economy forces), then the equilibrium contract will always be of length T. The following proposition presents the equilibrium for exogenous prices as well as endogenous prices such as they are given by Proposition 4.

PROPOSITION 7. *Suppose time is continuous and a rental contract can be of length T.*
(i) *In the sales market, the unique equilibrium is in mixed strategies:*

$$\begin{aligned} \widetilde{b} &= r\tfrac{C}{P-C} & \textit{and} \quad \widetilde{c} &= r\tfrac{P-D}{E-P+D} \\ &= r\tfrac{C}{(D+E-C)\alpha} & &= r\left[\tfrac{E}{(D+E-C)(1-\alpha)} - 1\right] \end{aligned} \tag{11}$$

since the equilibrium sales price is, as before, $P = (1-\alpha)\,C + \alpha\,(D+E)$.
(ii) *In the rental market, the unique equilibrium is in mixed strategies:*

$$\begin{aligned} \widetilde{b} &= r\tfrac{C}{p-C(1-e^{-rT})} & \textit{and} \quad \widetilde{c} &= \tfrac{r}{E(1-e^{-rT})/p-1} \\ &= r\tfrac{C}{(E-C)(1-e^{-rT})k} & &= r\left[\tfrac{E}{(E-C)(1-k)} - 1\right] \end{aligned} \tag{12}$$

when the equilibrium rental price is (analogous to Proposition 4):

$$\begin{aligned} \frac{p}{1-e^{-rT}} &= (1-k)\,C + kE, \textit{ where} \\ k &\equiv \frac{\alpha}{1-e^{-rT}+e^{-rT}\alpha}. \end{aligned} \tag{13}$$

(iii) *Once B has contacted S, there exists a rental contract which both B and S strictly prefer to selling if and only if:*

$$-D > \frac{P-C}{e^{rT}-1} \Leftrightarrow \tag{14}$$

$$\frac{-D}{E-C} > \frac{\alpha}{\alpha+e^{rT}-1}. \tag{15}$$

Part (i) is similar to Proposition 1, and in fact identical when the discount rate is $\delta = e^{-r\Delta}$, Δ is the length of a period, $\widetilde{b} = b/\Delta$, $\widetilde{c} = c/\Delta$, and one takes the limit as $\Delta \to 0$. At every point in time, if the sales market has ended, then the good is conserved (and purchased) with probability

$$\frac{\widetilde{b}}{\widetilde{b} + \widetilde{c}} = \frac{(1-\alpha) C/\alpha}{\alpha E + (1-\alpha)(C-D) + (1-\alpha) C/\alpha},$$

which we can rewrite to confirm Corollary 2.

Part (ii) of Proposition 7 is identical to Proposition 2 if $T = \Delta$ and $\Delta \to 0$. Part (iii) is similar to Proposition 3, but the effect of T is new. Remember that the disadvantage with a rental contract is that the players continue to randomize as soon as one rental contract has expired. If B and S can commit to a longer rental contract, then this disadvantage is somewhat mitigated, and a rental contract becomes more attractive compared to a sales contract. Thus, if T is sufficiently large, (14) always holds unless $D \geq 0$.

Parts (i) and (iii) hold whether the rental price is exogenous or endogenous. If we let the rental price be characterized by the generalized Nash bargaining solution in which the threat point is either that (a) S cuts or (b) B buys at price P, then the rental price must be given by (13). Thus, the present-discounted cost of renting always is a weighted average between C and E, intuitively increasing in the seller's bargaining power, α.

5.2 Multiple Buyers

The continuous time model 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 $D - P$ if i buys, and zero if $j \in N \backslash i$ buys or if S conserves. In the rental market, the payoffs are analogous. Let $\widetilde{b}$ represent the Poisson rate at which S is contacted by *some* buyer. Thus, in a symmetric equilibrium, every i contacts S at the rate $\widetilde{b}_i$ which satisfies $\left(1 - \widetilde{b}\right) = \left(1 - \widetilde{b}_i\right)^n \Leftrightarrow \widetilde{b}_i = 1 - \left(1 - \widetilde{b}\right)^{1/n}$. Perhaps surprisingly, most of the results continue to hold:

PROPOSITION 8. *Suppose there are n identical potential buyers. In the symmetric equilibrium, Proposition 7 continues to hold with the following modifications:*

(i) *Cutting increases in* n *in the sales market:*

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

(ii) *Cutting also increases in* n *in the rental market:*

$$\widetilde{c} = \frac{r + (1 - 1/n)\left(1 - e^{-rT}\right) b}{E\left(1 - e^{-rT}\right)/p - 1}.$$

In comparison to Proposition 7, the result is disappointing. If more countries benefit from conservation, a planner would be more eager to conserve the forest but the 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 benefits since other buyers may contact S and pay for conservation. This reduces i's willingness to contact S and, for i to still be willing to pay, S must cut at a faster rate.[36]

Nevertheless, the similarities to the one-buyer case may be more surprising than the differences. First, $\widetilde{b}$ 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 buy or rent, 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 the buyers do not gain from the presence of other buyers: the benefit that the other countries may pay for conservation cancels out with the cost of the faster cutting rate. For related reasons, the buy-versus-rental decision is also independent of n: in both markets, the payoffs to $i \in N$ as well as to S are unaffected by n.

So far, this subsection has described the *symmetric* equilibrium in which all buyers might buy with the same chance. This equilibrium is not stable, however: If $\widetilde{b}_i$ increased marginally, the best response for $j \neq i$ would be $\widetilde{b}_j = 0$. This, in turn, would motivate i to raise $\widetilde{b}_i$ to

[36] The outcome is still worse if the aggregate conservation value $\overline{E}$ 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 or 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.) In this situation renting would be more likely as n grows, since Proposition 7(iii) states that renting is more likely when the buyer's value is low.

Note that there is an analogy to the "Kitty Genovese" game (Osborne, 2003, Ch. 4.8), where the likelihood that someone calls the policy is decreasing in the number of observers to the crime. In that game, however, there is no player similar to the seller in the current game, and thus nothing reflects the increased cutting.

$\widetilde{b}$ as described by Proposition 7. This iterative process of best replies can never converge to the equilibrium with multiple active buyers, and the stable equilibria must be characterized by the game with one single buyer. This suggests that the one-buyer game in Sections 2-4 is of interest even though there may be several *potential* buyers interested in conservation. In the real world, the main actor on the buying side has so far been the UN-REDD program, while the single main contributor has been the Norwegian government.

5.3 Multiple Sellers

Multiple sellers can also be introduced into the model. There are several ways of doing this. This subsection presents two variations which ensure that the results above continue to hold. Other variants are mentioned at the end.

(a) Independence. Suppose there are multiple sellers, $j \in M \equiv \{1, ..., m\}$, who each own a conservation good characterized by C_j, D_j, and E_j. Following the reasoning above (Section 2.2), assume that a buyer's loss when multiple forests are cut is linearly separable. Thus, if a buyer purchases every forest in the set M_B while every forest in the set M_C is cut, where $M_B \cup M_C = M$, then the buyer's payoff would be:

$$\sum_{j \in M_B} (D_j - P_j) - \sum_{j \in M_C} E_j.$$

In this situation, whether forest $j \in M$ is purchased, conserved, or cut does not influence any player's payoff when he is considering risking the purchase, conservation, or cutting of another forest. It follows that the game between seller $j \in M$ and the buyer(s) is strategically independent of the outcome or the play with another seller. Thus, each of the games (one for each seller) can be analyzed in isolation, exactly as is done above.

(b) Satiation. An alternative assumption is to assume that a buyer experiences the same loss E if and only if *all* forests are cut. The conservation of one of them suffices, so two or more forests will never be purchased. In this case, it is intuitive that as soon a buyer has contacted one of the sellers, the other sellers will find it optimal to cut immediately. The price which thereafter is negotiated between the contacted seller and the contacting buyer (or renter) is thus the same as described above.[37] Given this game, it is easy to verify that

[37] If instead cutting takes some time, such that a buyer can contact a second seller after he fails to agree

there cannot be any symmetric equilibrium in which either all sellers cut at the same time (since the buyer would then strictly benefit from immediately contacting one of the sellers), or in which multiple sellers $j \in M$ cut at interior rates $\widetilde{c}_j \in (0, \infty)$, since the buyer(s) will then strictly benefit from not contacting the sellers until at most one forest remains. Hence, at most one seller can cut at an interior rate.

In sum, in every stationary equilibrium, all but one seller cut immediately, and the subgame between the remaining seller and the buyer(s) is exactly as described above. If the sellers are heterogeneous in that C_j and D_j are forest-specific, then a buyer is willing to defer buying one of the other forests only if that would have led to lower payoffs. When the prices are endogenous, as described above, it follows that the one remaining seller in the sales market must have the lowest possible $C_j - D_j$, since that generates the lowest price for conservation and thus the highest payoff to the buyer. In the rental market, the single remaining seller must have the lowest possible C_j, for the analogous reason.

PROPOSITION 9. *Suppose that there are multiple sellers and conservation goods.*
(i) *With Independence, Propositions 1-8 above describe the equilibrium play between the buyer(s) and each of the sellers.*
(ii) *With Satiation, in every stationary equilibrium all but one of the sellers cut immediately and the subsequent play between the remaining seller and the buyer(s) is described by Propositions 1-8. The identity of the single remaining seller must satisfy*

$$j \in \arg\min_{l \in M} C_l - D_l$$

in the sales market, and

$$j \in \arg\min_{l \in M} C_l$$

---

with the first, then the threat point is more favorable to the buyer and the Nash bargaining outcome predicts a lower price:

$$P = \left(1 - \alpha^2\right) C + \alpha^2 (D + E).$$

The lower price means that a buyer has a preference for buying while both forests still exist, unless the rate of cutting during that phase is low. With two sellers and one buyer, one can show that each seller must cut at the Poisson rate

$$c = \frac{r}{2} \left[\frac{C - D}{\alpha (1 - \alpha) (D + E - C)} + \frac{\alpha}{1 - \alpha} \right],$$

while the buyer will contact each of the sellers with the Poisson rate

$$b = r \frac{2C}{\alpha^2 (D + E - C)}.$$

Thus, small modifications in the multiple-seller model can have substantial consequences for the results, suggesting that further research is warranted.

in the rental market.

In the case of Independence, if there are multiple homogeneous buyers, then there can be different active buyers for each of the sellers. For each seller, stability requires that there is at most one active buyer, just as before.

The analysis should not end here. Rather than the two extreme assumptions of Independence and Satiation, it would be both more reasonable and more general to let the buyers face conservation values that are arbitrary nonlinear functions of the stocks of conserved forests. This situation could create interesting strategic games between the different sellers as well as between the buyers - raising a host of new issues that deserve to be investigated in future research.

6 Conclusions

This paper introduces the notion of conservation goods and shows that they are quite different from traditional goods. A buyer is satisfied with the status quo and is willing to buy only if the seller is likely to end conservation; but the seller conserves if she believes the buyer will pay. Reasonable equilibria are in mixed strategies, implying that conservation ends with a positive probability - or gradually at a positive rate. These findings are consistent with tropical deforestation occurring in the South even when the North has a larger value of conservation.

The analysis also uncovers a new trade-off between buying and leasing. On the one hand, rental markets are also characterized by mixed-strategy equilibria, so conservation inevitably ends, sooner or later, as long as the good is not purchased. This suggests that conservation is a more likely outcome in a sales market than in a rental market. On the other hand, renting implies that the seller has an incentive to protect or maintain the good, and this might be less expensive than if the buyer (which might be a foreign country) protects or maintains the good. By comparison, the results predict that domestic conservation will be bought, while conservation in other countries (where protection would be expensive) will be rented. This seems consistent with anecdotal evidence: REDD contracts are rental arrangements; national parks are not.

The model above is rather simple, but it has proven flexible enough to be extended in a number of directions. Nonetheless, many questions remain open. To isolate the key feature of conservation goods, I have abstracted from uncertainty, private information, reputation-building, learning, moral hazard, and more complicated utility functions or bargaining procedures. These aspects should be examined in future research so that we can better understand the important and puzzling nature of conservation markets.

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7 Appendix: Proofs

Proof of Proposition 1. At the start of each period, the continuation values for B and S depends on the equilibrium strategies:

$$
\begin{aligned}
V_B(b,c) &= b(D-P) + (1-b)\left[-cE + (1-c)\,\delta V_B(b,c)\right];\\
V_S(b,c) &= bP + (1-b)\left[cC + (1-c)\,\delta V_S(b,c)\right].
\end{aligned}
$$

The game is a quitting game and B's decision is whether to stop and get the payoff $D-P$ or to continue. If continuation is a best response, it remains a best response in the subsequent periods and B's payoff is:

$$
V_B(0,c) = -\frac{cE}{1-\delta(1-c)} \geq V_B(1,c) = D-P \text{ if } c \leq \frac{P-D}{E-\delta(P-D)}(1-\delta).
$$

It follows that B's best response is

$$
\begin{aligned}
b &= 0 \text{ if } c < \frac{P-D}{E-\delta(P-D)}(1-\delta),\\
b &\in [0,1] \text{ if } c = \frac{P-D}{E-\delta(P-D)}(1-\delta),\\
b &= 1 \text{ if } c > \frac{P-D}{E-\delta(P-D)}(1-\delta),
\end{aligned}
\tag{16}
$$

where $(1-\delta)(P-D)/[E-\delta(P-D)] \in (0,1)$ if $P > D$. If $P < D$, as for traditional goods, then $b=1$ for every $c \in [0,1]$. If $P = D$, the unique best response is $b = 1$ if $c > 0$, while any $b \in [0,1]$ is a best response if $c = 0$.

S's decision at the cutting stage is whether to cut to get C or to continue. If continuation is a best response, it remains a best response in the following periods and S's payoff is:

$$
\delta V_S(b,0) = \frac{\delta bP}{1-\delta(1-b)} \geq V_S(b,1) = C \text{ if } b \geq \frac{C}{P-C}\frac{1-\delta}{\delta}.
$$

It follows that S's best response is

$$
\begin{aligned}
c &= 0 \text{ if } b > \frac{C}{P-C}\frac{1-\delta}{\delta},\\
c &\in [0,1] \text{ if } b = \frac{C}{P-C}\frac{1-\delta}{\delta},\\
c &= 1 \text{ if } b < \frac{C}{P-C}\frac{1-\delta}{\delta},
\end{aligned}
$$

where $C(1-\delta)/\delta(P-C) \in (0,1)$ if $P > C/\delta$. So, if $P > C/\delta$ and $P > D$ (case (iii)), then the unique equilibrium is in mixed strategies. If $P < C/\delta$ (case (i)), then $c = 1$ is the unique best response for every $b \in [0,1]$. If $P = C/\delta$ (case (ii)), then $c = 1$ is the unique best response if $b > 0$, while any $c \in [0,1]$ is a best response if $b = 1$. Combined with (16), the equilibrium must satisfy:

$$\begin{array}{llll}
\text{(a)} \quad b = \frac{C}{P-C}\left(\frac{1-\delta}{\delta}\right) & \text{and} \quad c = \frac{(1-\delta)(P-D)}{E-\delta(P-D)} & \text{if} \quad P \in \left(\max\left\{\frac{C}{\delta}, D\right\}, D+E\right); \\
\text{(b)} \quad b = 1 & \text{and} \quad c = 1 & \text{if} \quad P \in \left[C, \frac{C}{\delta}\right); \\
\text{(c)} \quad b = 1 & \text{and} \quad c = 0 & \text{if} \quad P \in \left(\frac{C}{\delta}, D\right); \\
\text{(d)} \quad b \in \left[\frac{C}{P-C}\left(\frac{1-\delta}{\delta}\right), 1\right] & \text{and} \quad c = 0 & \text{if} \quad P = D > \frac{C}{\delta}; \\
\text{(e)} \quad b = 1 & \text{and} \quad c \in \left[\frac{(1-\delta)(P-D)}{E-\delta(P-D)}, 1\right] & \text{if} \quad P = \frac{C}{\delta}; \\
\text{(f)} \quad b \in \left[0, \frac{C}{P-C}\left(\frac{1-\delta}{\delta}\right)\right] & \text{and} \quad c = 1 & \text{if} \quad P = D + E.
\end{array}$$

When attention is limited to $P \in (\max\{C, D\}, D+E)$, Proposition 1 follows. *QED*

Proof of Proposition 2. The proof is analogous to the proof of Proposition 1, and it follows as a special case from the proof of Proposition 7. The proof is thus omitted here, but available upon request. *QED*

Proof of Proposition 3. (i) First, note that if $E < (\leq) C$, there is no rental price that makes both players (strictly) better off than cutting, so the rental market does not exist. Thus, assume $E > C$.

In the sales market, $V_B = D - P$. In the rental market, $V_B = -p/(1-\delta)$ since renting forever in every period is a best response. If B expects to revert to the sales market in the following period, then $V_B = -p + \delta(D - P)$. In both cases, B is indifferent between renting and buying if:

$$P = \frac{p}{1-\delta} + D \Leftrightarrow p = (1-\delta)(P - D). \tag{17}$$

Once B has contacted S to buy, S expects the payoff P. If S accepts a one-period rental agreement instead, her payoff is $p + \delta V_S$. If the following periods are characterized by the sales market, then, if $D < P$, $V_S = \min\{P, C/\delta\}$. If $D > P$, then $V_S = P$. So, there exists a p which makes both B and S strictly prefer a rental contract in the present period if and only if:

$$\begin{array}{lrcl}
\text{(i)} & -D & > & \dfrac{\delta P}{1-\delta} - \dfrac{C}{1-\delta} \text{ if } P > C/\delta \text{ and } P > D; \\
\text{(ii)} & -D & > & 0 \text{ if } P \leq C/\delta \text{ or if } P < D.
\end{array}$$

If $D > P$, both conditions fail and renting is never better than buying. If $D = P$, then $V_S = P$ if $P \leq C/\delta$, while $V_S \in [C/\delta, P]$ if $C/\delta < P$; but regardless of $V_S \in [C/\delta, P]$, there is no p such that both players can strictly gain by renting. When we combine (i), (ii) and (1), we can conclude that renting is better if and only if (6) holds.

If B and S instead anticipate that the following periods will also be characterized by the rental market with some equilibrium price $\overline{p}$, then $V_S = \min\{\overline{p}/(1-\delta), C/\delta\}$. In this situation, there exists a p which makes both B and S strictly prefer renting today rather than trading at price P if and only if:

$$\begin{aligned}
(1-\delta)(P-D)+\delta V_S &> P \Rightarrow \\
-D &> \frac{\delta P}{1-\delta}-\frac{C}{1-\delta} \text{ if } \overline{p}/(1-\delta) > C/\delta; \qquad (18)\\
-D &> \frac{\delta P}{1-\delta}-\frac{\delta \overline{p}}{(1-\delta)^2} \text{ if } \overline{p}/(1-\delta) \leq C/\delta \Rightarrow \\
-D &> \frac{\delta P}{1-\delta}-\frac{\delta}{1-\delta}\min\left\{\frac{\overline{p}}{1-\delta},\frac{C}{\delta}\right\}. \qquad (19)
\end{aligned}$$

These conditions are more likely to hold for some $\overline{p}$ if this $\overline{p}$ is large, but the largest $\overline{p}$ which B is willing to accept is given above by (17). Thus, condition (19) becomes:

$$-D > \max\left\{\frac{\delta P}{1-\delta}-\frac{\delta(P-D)}{1-\delta},\frac{\delta P-C}{1-\delta}\right\} \Rightarrow (6).$$

(ii) The proof of part (ii) is analogous and thus omitted. *QED*

Proof of Proposition 4. (i) This part is as described in Section 2. (ii) If B rents at p this period, anticipating the equilibrium rental price $\overline{p}$ in the following periods, then B's payoff is:

$$-p-\frac{\delta\overline{p}}{1-\delta},$$

while, from Proposition 2, S's payoff is

$$p+\delta V_S = p+\min\left\{C,\frac{\delta\overline{p}}{1-\delta}\right\}.$$

(a) Consider the default outcome "cut," where S immediately cuts if the negotiations on the rental price fail. Relative to this, B's surplus when renting at p is

$$\Delta_B^{rent} = E-p-\frac{\delta\overline{p}}{1-\delta},$$

while S's bargaining surplus is:

$$\Delta_S^{rent} = p+\min\left\{C,\frac{\delta\overline{p}}{1-\delta}\right\}-C.$$

The generalized Nash bargaining solution requires that

$$\begin{aligned}
\Delta_S^{rent} &= \alpha\left(\Delta_S^{rent}+\Delta_B^{rent}\right)\\
&= \alpha\left(\min\left\{C,\frac{\delta\overline{p}}{1-\delta}\right\}-\frac{\delta\overline{p}}{1-\delta}+E-C\right) \Rightarrow \\
p &= (1-\alpha)C+\alpha E-(1-\alpha)\min\left\{C,\frac{\delta\overline{p}}{1-\delta}\right\}-\alpha\frac{\delta\overline{p}}{1-\delta}. \qquad (20)
\end{aligned}$$

In equilibrium, $p = \overline{p}$. If $C \leq \frac{\delta \overline{p}}{1-\delta}$, (20) becomes:

$$p = (1-\alpha) C + \alpha E - (1-\alpha) C - \alpha \frac{\delta p}{1-\delta} \Rightarrow \frac{p}{1-\delta} = \frac{\alpha}{1-\delta+\delta\alpha} E.$$

The condition $C \leq \frac{\delta \overline{p}}{1-\delta}$ does indeed hold if:

$$C \leq \frac{\delta\alpha}{1-\delta+\delta\alpha} E \Leftrightarrow \alpha \geq \frac{C}{E-C} \frac{1-\delta}{\delta}.$$

If instead $C > \frac{\delta \overline{p}}{1-\delta}$, then (20) becomes (when $p = \overline{p}$):

$$p = (1-\alpha) C + \alpha E - (1-\alpha) \frac{\delta p}{1-\delta} - \alpha \frac{\delta p}{1-\delta} \Rightarrow \frac{p}{1-\delta} = (1-\alpha) C + \alpha E.$$

The condition $C > \frac{\delta \overline{p}}{1-\delta}$ does indeed hold if

$$C > \delta (1-\alpha) C + \delta \alpha E \Rightarrow C > \frac{\delta\alpha}{1-\delta+\delta\alpha} E. \tag{21}$$

So, if C is larger than this threshold, then S would rather cut than wait for a future rental agreement, and B needs to rent in every period with certainty. Bargaining failure leads to cutting so p will reflect the level of both C and E. However, as $\delta \to E$, (21) requires that $C > E$, which is never satisfied for conservation goods in the rental market. In summary,

$$\frac{p}{1-\delta} = \max \left\{ (1-\alpha) C + \alpha E, \frac{\alpha}{1-\delta+\delta\alpha} E \right\} \Leftrightarrow (17).$$

(b) Consider the threat point "sale," where B buys at P if the negotiations on the rental price fail. Relative to this, B's surplus when renting at p is

$$\Delta_B^{sale} = -p - \frac{\delta \overline{p}}{1-\delta} - D + P,$$

while S's bargaining surplus is:

$$\Delta_S^{sale} = p + \min \left\{ C, \frac{\delta \overline{p}}{1-\delta} \right\} - P.$$

The generalized Nash bargaining solution requires

$$\Delta_S^{sale} = \alpha \left(\Delta_S^{sale} + \Delta_B^{sale} \right) = \alpha \left(\min \left\{ C, \frac{\delta \overline{p}}{1-\delta} \right\} - \frac{\delta \overline{p}}{1-\delta} - D \right) \Rightarrow (20).$$

The rest of the proof follows the same steps as after (20) in part (a). *QED*

Proof of Proposition 5. (i) First, note that the set of equilibria must be a subset of those permitted by Proposition 1. Furthermore, we cannot have $P < C/\delta$, since then S prefers $c = 1$ and thus B is willing to accept the price $D+E$; a contradiction. If $P \in (C/\delta, D+E)$, we know that b and c are as characterized by Proposition 1(iii) and B is indifferent trading at P, which is thus the highest price B is willing to accept. Consequently, S proposes exactly this price. This reasoning also holds when $P = C/\delta$. However, if $c > (1-\delta)(P-D)/[E-\delta(P-D)]$ at $P = C/\delta$, B would strictly prefer to buy and, hence, accept to buy at a higher price; a contradiction. If $P = D+E$, B is (indifferent and) willing to contact S and accept P when $c = 1$, so S proposes exactly this price. For S, $c = 1$ is a best response for every $b \leq C(1/\delta - 1)/(P-C)$.

(ii) The proof for part (ii) is analogous to part (i) and thus omitted. *QED*

Proof of Proposition 6. (i) First, I prove that (10) must hold for $s \in S^w$. Let $U_B(t)$ and $U_S(t)$ be the *interim* continuation values for B and S just before the cutting stage in period t. I allow B and S to renegotiate (also) at the interim stage. Let b and c be defined by (2) in Proposition 1.

Lemma 1. *If $s \in S^w$, then for every $t > 1$, (a) $b_t \leq b$ and (b) $c_t \leq c$.*

Proof. The proof is by contradiction.

(a) Suppose $s \in S^w$ and that for some $t > 1$, $b_t > b$. This can be optimal only if $-(P-D) \geq U_B(t)$ and $c_t \geq c$, which implies that $U_S(t) = C$. At $t-1$, S's unique best response is $c_{t-1} = 0$, since then $U_S(t-1) = \delta[b_t P + (1-b_t)U_S(t)] > \delta[bP + (1-b)C] = C = U_S(t)$. Also, note that $U_B(t-1) = -\delta(P-D) > -(P-D) \geq U_B(t)$. In sum, $U_B(t-1) > U_B(t)$ and $U_S(t-1) > U_S(t)$, so at interim period $t-1$ both B and S strictly prefer at interim period t to renegotiate to the equilibrium.

(b) If for some $t > 1$, $c_t > c$, then B's response is $b_t = 1$. This contradicts (a). *QED*

Lemma 2. *If $s \in S^w$, then for every $t > 2$, (a) $b_t \geq b$ and (b) $c_t \geq c$.*

Proof. (a). Suppose $b_t < b$ for $t > 2$. Then, we must have $c_{t-1} = 1$ at $t > 1$, which contradicts Lemma 1(b).

(b) Suppose $c_t < c$ for $t > 1$. Then, $b_t = 0$, which contradicts part (a). *QED*

Second, we can use Lemma 1 and Lemma 2 to construct the set S^w. In particular, $s \in S^w$ if and only if one of these cases describes the equilibrium:

$$\begin{aligned}
(1)\ b_t &= b \text{ and } c_t = c\ \forall\ t \geq 1. \\
(2)\ b_1 &\in [0,1],\ c_1 = c,\ b_t = b, \text{ and } c_t = c\ \forall t > 1. \\
(3)\ b_1 &= 0,\ c_1 < c,\ b_t = b, \text{ and } c_t = c\ \forall t > 1. \\
(4)\ b_1 &= 1,\ c_1 > c,\ b_t = b, \text{ and } c_t = c\ \forall t > 1. \\
(5)\ b_1 &= 1,\ c_1 = 1,\ b_2 < b,\ c_2 = c,\ b_t = b, \text{ and } c_t = c\ \forall t > 2. \\
(6)\ b_1 &= 1,\ c_1 = 1,\ b_2 = 0,\ c_2 < c,\ b_t = b, \text{ and } c_t = c\ \forall t > 2.
\end{aligned}$$

By comparison, it is straightforward to verify that there is no $s \in S^w$ and time such that both players strictly benefit from switching to another $s' \in S^w$. This holds also if the players can switch to another weakly renegotiation-proof equilibrium at the interim stage (when S is the next player to act). To see this, simply note that at the interim stage, the set of weakly renegotiation-proof equilibria S^w_+ consists of just the set of cases (1)-(6) but modified so that the first entry involving b_1 is omitted from each case. It follows that if $s \in S^w$, then $s \in S^s$. Since $S^s \subseteq S^w$, it follows that $S^s = S^w$. Analogously, $S^s_+ = S^w_+$. This completes the proof.

(ii) The proof for the rental market follows the same lines except that in the proof of Lemma 1(a), $(P-D)$ should be replaced by $p/(1-\delta)$. *QED*

Proof of Proposition 7. The proposition follows from Proposition 8 when setting $n = 1$.

Proof of Proposition 8. (i) *The sales market:* The aggregate $b = \sum_{i \in N} b_i$ that makes S willing to randomize is given by:

$$\begin{aligned} C &= \int_0^\infty Pbe^{-t(r+b)}dt = \frac{bP}{r+b} \Rightarrow \\ b &= \frac{rC}{P-C}. \end{aligned} \tag{22}$$

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

$$\begin{aligned} P - D &= \int_0^\infty (cE + b_{-i} \cdot 0)\, e^{-t(r+b_{-i}+c)}dt = \frac{cE}{c + b_{-i} + r} \Rightarrow \\ c &= \frac{(P-D)(b_{-i}+r)}{D+E-P} = \frac{(P-D)(b(n-1)/n + r)}{D+E-P}, \end{aligned} \tag{23}$$

where the equality $b_i = b/n$ is used since every b_{-i} must be the same in order for (23) to hold for all $i \in N$.
(ii) *The rental market:* If S is willing to mix, then $V_S = C$ and:

$$\begin{aligned} C &= \int_0^\infty \left(p + Ce^{-rT}\right) be^{-t(r+b)}dt = \frac{b\left(p + Ce^{-rT}\right)}{r+b} \Rightarrow \\ b &= r\frac{C}{p - C\left(1 - e^{-rT}\right)}. \end{aligned}$$

If buyer $i \in N$ is willing to rent and to pay p at frequency T, then $V_i = -p/\left(1 - e^{-rT}\right)$. If i is also willing to wait, then the following also hold:

$$\begin{aligned} V_i &= -\int_0^\infty \left(cE + b_{-i}\left[-e^{-rT}V_i\right]\right) e^{-t(r+b_{-i}+c)}dt \\ &= -\frac{cE - b_{-i}e^{-rT}V_i}{r + b_{-i} + c} \Rightarrow \\ c &= \frac{-(b_{-i}+r)V_i + b_{-i}e^{-rT}V_i}{E + V_i} = \frac{\left(r + b_{-i}\left(1 - e^{-rT}\right)\right) p/\left(1 - e^{-rT}\right)}{E - p/\left(1 - e^{-rT}\right)} \\ &= \frac{\left[r/\left(1 - e^{-rT}\right) + b\left(1 - 1/n\right)\right] p}{E - p/\left(1 - e^{-rT}\right)}. \end{aligned}$$

The endogenous rental price. If B rents at p this period, anticipating the equilibrium rental price $\overline{p}$ in the future, then B's payoff is:

$$-p - \frac{e^{-rT}\overline{p}}{1 - e^{-rT}},$$

while S' payoff is

$$p + e^{-rT}V_S = p + Ce^{-rT}.$$

(a) Consider the threat point "cut", where S immediately cuts if the negotiations on the rental price fail. Relative to this, B's surplus when renting at p is

$$\Delta_B^{rent} = E - p - \frac{e^{-rT}\overline{p}}{1-e^{-rT}},$$

while S bargaining surplus is:

$$\Delta_S^{rent} = p + Ce^{-rT} - C.$$

The generalized Nash bargaining solution requires

$$\begin{aligned} \Delta_S^{rent} &= \alpha\left(\Delta_S^{rent} + \Delta_B^{rent}\right) = \alpha\left(E - \frac{e^{-rT}\overline{p}}{1-e^{-rT}} - C\left(1-e^{-rT}\right)\right) \Rightarrow \\ p &= \alpha E - \alpha\frac{e^{-rT}\overline{p}}{1-e^{-rT}} + (1-\alpha)\,C\left(1-e^{-rT}\right). \end{aligned} \tag{24}$$

In equilibrium, $p = \overline{p}$, so (24) becomes:

$$\begin{aligned} p\left(1-e^{-rT}(1-\alpha)\right) &= \alpha\left(1-e^{-rT}\right)E + (1-\alpha)\,C\left(1-e^{-rT}\right)^2 \Rightarrow \\ \frac{p}{1-e^{-rT}} &= \frac{\alpha E + (1-\alpha)\left(1-e^{-rT}\right)C}{1-e^{-rT}+e^{-rT}\alpha}. \end{aligned}$$

(b) With the threat point "sale", where B buys at P if the negotiations on the rental price fails, then the same analysis as in (a) leads to the same p for the same reason as in the proof of Proposition 4.

(iii) *By comparison:* Since the buyer is willing to immediately buy in the sales market, and to always rent in the rental market, his payoffs in the two markets are identical if:

$$\frac{p}{1-e^{-rT}} = P - D. \tag{25}$$

Once B has contacted S, S strictly prefers the rental contract if and only if:

$$P < p + e^{-rT}V_S = p + e^{-rT}C. \tag{26}$$

Thus, for the most expensive rental contract that B would be willing to accept (i.e., ensuring that (25) holds), S strictly prefers the rental contract (the inequality (26) is satisfied) if:

$$\begin{aligned} P &< \left(1-e^{-rT}\right)(P-D) + e^{-rT}C \Rightarrow \\ Pe^{-rT} &< -\left(1-e^{-rT}\right)D + e^{-rT}C \Rightarrow \\ P - C &< -\left(e^{rT}-1\right)D \Rightarrow (14). \end{aligned} \tag{27}$$

Substituting for P, we get (15). *QED*

Proof of Proposition 9 follows from the reasoning in the text.