CONSERVATION CONTRACTS
AND
POLITICAL REGIMES*

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August 2015

Abstract
Motivated by tropical deforestation, we present a model in which extraction generates profits while conservation requires costly monitoring. With “strong” districts, protection is inexpensive, extraction sales-driven, and extraction in one district reduces the profit for the others. “Weak” districts benefit when neighbors extract since this reduces the pressure on their resource, and their monitoring costs. Consequently, decentralization increases conservation if and only if districts are weak. We derive the optimal contract for a principal who benefits from conservation and show that decentralized contracts are better if the districts are weak. The districts, in contrast, prefer decentralization if they are strong.

Keywords: Deforestation, resource extraction, conservation, contracts, externalities, leakage, crime displacement, state capacity, centralization, decentralization, institutional change, climate change, REDD, PES.

*We are grateful to audiences at Harvard University, London School of Economics, Warwick University, University of Zurich, Toulouse School of Economics, Paris Ecole Polytechnique, Norwegian School of Economics, the World Bank, Universidad Carlos III, University of Copenhagen, University of Oslo, and the 2015 Environmental Protection and Sustainability Forum in Bath. We are especially thankful to the comments of Arild Angelsen, Philippe Delacote, Jonas Hjort, Chuck Mason, Halvor Mehlum, Kalle Moene, Nicola Persico, Torsten Persson, Francois Salanie, Steve Shavell, Kathryn Spier, Jon Strand, and Ragnar Torvik. Judith Levy assisted with the editing. Please contact us at bard.harstad@econ.uio.no and torben.mideksa@econ.uio.no.
1 Introduction

Natural resources are being depleted all across the world. They are managed and extracted by independent countries, even though conservation may also benefit third parties. The economics and politics of resource extraction are inextricable and must be better understood before conservation can succeed. This paper presents a new model of conservation and derives the contract preferred by a third party that benefits from conservation. We also show how the contract both influences, and should be influenced by, the countries’ political regimes and state capacities. Payments for environmental services (PES) are important in many situations, and the resource in our model could be fossil fuels or land use quite generally, but our analysis is motivated in particular by deforestation in the tropics and the emergence of contracts on reducing emissions from deforestation and forest degradation (REDD).

Deforestation in the tropics is an immensely important problem. The cumulative effect of deforestation amounts to about one quarter of anthropogenic greenhouse gas emissions, which generate global warming (Edenhofer et al., 2014). The annual contribution from deforestation to CO$_2$ emissions is around ten percent (Stocker et al., 2013), and the percentage is even higher for other greenhouse gases. Sadly, tropical forest loss has been increasing at an average rate of 2101 km$^2$ each year since 2000. In addition to the effect on global warming, deforestation leads to huge losses in biodiversity. The negative externalities of deforestation amount to $2-4.5 trillion a year, according to The Economist (2010).

Third parties are therefore interested in conservation. With the help of donor countries (in particular, Norway, Germany, and Japan), the World Bank and the United Nations are already offering financial incentives to reduce deforestation in a number of countries. Estimates suggest that deforestation could be halved at a cost of $21-35 billion per year, or reduced by 20-30 percent at a price at $10/tCO$_2$. Conservation contracts are thus likely to be an important part of future climate change policies and treaties. They are also favored by economists who view them as the natural Coasian solution (Alston and Andersson, 2011).

It is therefore essential to understand how conservation contracts should be designed. So far, however, there is little theory that can guide real-world contract designers. A useful theory must take several facts into account. First, the causes of deforestation differ across regions: while local governments sell logging concessions in some countries, other countries

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1See Engel et al. (2008) for PES more generally. See Karsenty (2008) and Parker et al. (2009) for an explanation of the difference between alternative concepts such as RED, REDD, and REDD+.

2Hansen et al. (2013). Harris et al. (2012) offer more precise estimates of deforestation between 2000 and 2005. The overall message that tropical deforestation has been increasing remains robust.

3See Edenhofer et al. (2014) and Busch et al. (2012), respectively.

4Even for other types of resources, such as fossil fuel reserves, a climate coalition’s optimal policy may be to pay nonparticipants to conserve particular reserves (Harstad, 2012).
fight illegal logging for timber or the burning of the forest for agriculture. Second, markets for timber and agricultural products are integrated and conservation in one region can lead to increased deforestation elsewhere: for conservation programs in the U.S. west, the leakage rate (i.e., the increased deforestation elsewhere per unit conserved in the west) was 43 percent at the regional level, 58 percent at the national level, and 84 percent at the continental level; for the 1987-2006 conservation program in Vietnam, the leakage rate was 23 percent, mostly due to increased logging in neighboring Cambodia and Laos. The presence of leakage is not surprising: conservation reduces the supply of forest products, and the price thus increases; a higher price increases deforestation (Kaimowitz and Angelsen, 1998) and the cost of protection (as in Ross, 2001) elsewhere.

As a third fact, the political regime seems to play an important, but puzzling, role. Decentralization of forest management has reduced deforestation in some regions, like the Himalayas, see Baland et al. (2010) or Somanathan et al. (2009). The reverse effect has been documented in other places, like Indonesia: "Increases in the number of political jurisdictions lead to increased deforestation and lower timber prices" (Burgess et al., 2012: 1701).

Despite all these differences, contracts tend to be similar across countries, and targeted mainly at the national governments. Norway, for example, recently declined to contract with the region Madre de Dios in Peru and it stated that it would only contract at the national level. Even when districts are in charge of managing the forest, scholars such as Phelps et al. (2010) argue that the provision of conservation contracts will, in any case, motivate districts to centralize authority.

These facts and claims raise a number of important questions. How can we explain the inconsistent effect of the political regime on conservation? What is the optimal conservation contract, and how does it depend on state capacities or the driver of deforestation? Is it wise to contract with central governments only, or can local contracts be more effective? Can the existence of conservation contracts actually influence regime change, and when would that be beneficial and increase conservation?

Our first contribution is to provide a tractable model that can address all the questions above. In the model, each country or district may benefit from extracting its resource, but the price of the harvest is reduced by the aggregate supply. To protect the remaining part of the resource, the monitoring effort must ensure that the expected penalty is at least as large as the harvest price motivating illegal logging. Thus, a district may want to limit the amount that is protected, and let some of it be harvested and offered to the market, since this reduces

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5 The numbers for the U.S. are from Murray (2008) and Murray et al. (2004); Meyfroidt and Lambin (200) provided the study of Vietnam. Atmadja and Verchot (2012) summarize the findings on forest conservation leakage: the estimates vary widely between 5 and 95 percent, but typical numbers are around 40 percent.
the price and thus the monitoring cost on the part that is to be protected.

The model can explain the inconsistent evidence regarding the effect of the political regime. Suppose districts are "strong" in that extraction is sales-driven and motivated mainly by the profit that can be earned by the districts. In this case, a district benefits if the neighbors conserve since that reduces their supply and the harvest price (and profit) increases. The positive (pecuniary) externality from conservation would be internalized by a central government, so centralizing authority will increase conservation. Alternatively, suppose logging is illegal or districts are "weak" in that they are unable to capture much of the profit, and they find it expensive to protect the resource. In that case, a district loses when neighbors conserve, since this increases the price and the pressure on the resource, and thus also the monitoring cost when the resource is protected. This negative externality implies that when authority is centralized, conservation declines. Consistent with our theory, countries in which decentralization reduced deforestation has been referred to as weak: in Nepal, "the Forest Department was poorly staffed and thus unable to implement and enforce the national policies, and deforestation increased in the 1960s and 1970s" (Shyamsundar and Ghate, 2014: 85). In Indonesia, where decentralization increased deforestation, the state is stronger: "Deforestation in Indonesia is largely driven by the expansion of profitable and legally sanctioned oil palm and timber plantations and logging operations" (Busch et al., 2015: 1328).6

Our second contribution is to derive the optimal conservation contract. If there is a single district, a simple contract (similar to a Pigou subsidy) implements the first best, regardless of the other parameters in the model. This finding, in isolation, supports today’s use of contracts that are linear in the amount of avoided deforestation. With multiple districts, however, one district finds it optimal to extract more when the neighbors conserve or sign conservation contracts: the resulting higher price makes it profitable to extract if the district is strong, and expensive to protect if the district is weak. This leakage makes a contract less effective, and the optimal contract is weaker. Furthermore, contracting with one district generates externalities on the others’ outside option. The donor cannot exploit this externality and the equilibrium contracts are too weak, leading to too much extraction, when districts are strong and the externality positive. When the districts are weak and the externality negative, however, there is too much conservation in equilibrium, since the donor takes advantage of the negative externality on the other districts for each conservation contract that is offered.

When districts are strong and extraction is sales-driven, the positive externality means that a central government would be more willing to conserve and adhere to a conservation

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6 The literature on state capacity often refers to states in East Asia as strong; see the references in Acemoglu et al. (2015).
contract. That willingness can be exploited by the donor, who therefore prefers to contract with central governments rather than with local governments. This result is reversed when the externality is negative, i.e., when districts are weak and extraction is protection-driven. The negative externality means that a central government becomes reluctant to signing the conservation contract, and the donor will find that districts adhere to the contract at a lower price. Thus, the donor benefits from local contracts if and only if the districts are weak.

The districts themselves have the exact opposite interest. If they could, they would choose a political regime that forces the donor to offer larger transfers for each unit that is conserved. Consequently, the districts prefer to centralize authority when they are weak, and to decentralize when they are strong. The presence of the donor may contribute to these incentives for institutional change. An induced regime change would not only make the conservation contracts expensive, it would also increase extraction. Our final contribution is to specify conditions under which the induced institutional change increases extraction by more than the conservation contracts reduce it. Under these conditions, the presence of the donor does more harm than good.

After discussing our contribution to the literature, Section 3 presents our model of conservation and extraction, which we solve in Section 4. Conservation contracts are analyzed in Section 5, while Section 6 endogenizes the political regime and studies when the donor prefers contracting with central rather than local governments. After a brief concluding section, the Appendix provides all the proofs.

2 Contributions to the Literature

As discussed above, our model is consistent with the evidence on leakage and our results may explain the puzzling effect of the political regime. Our theory also contributes to the literature on the causes of resource extraction and deforestation. The literature has identified such causes as optimal land-use, income growth and demand for forest products, corruption, costly enforcement, illegal logging, and other institutional weaknesses. Our first contribution to this literature is to provide a tractable workhorse model that can be used for all these alternative drivers. When the levels of the parameters in our model are suitably adjusted, it can be applied whether the deforestation driver is corruption, revenue generation at the local

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7See, for optimal land use models: Hartwick et al. (2001); income growth and demand for forest products: Foster and Rosenzweig (2003); corruption: Burgess et al. (2012); Amacher et al. (2012); Delacote (2011); Robinson and Lokina (2011); costly enforcement: Clarke et al. (1993); Dokken et al. (2014); illegal logging: Amacher et al. (2007); Clarke et al. (1993); Robinson et al. (2013); or for other institutional weaknesses: Angelsen (2001); Mendelsohn (1994). Kaimowitz and Angelsen (1998) and Angelsen and Kaimowitz (1999) provide a detailed review of the earlier literature regarding economic models of tropical deforestation.
level, illegal logging by small farmers, or by large corporations.

In fact, our theoretical framework draws from, and ties together, the literatures on state capacity, the resource curse, and crime displacement. The terminology "strong" vs. "weak" states (or districts), is borrowed from the literature on state capacity (Acemoglu, 2005; Besley and Persson, 2009, 2010, 2011), which refers to states as weak if they are unable to control the economy, support private markets, or raise revenues. The role of institutions has also been emphasized by the literature on the resource curse, which has found that a larger resource stock is beneficial for a country with good institutions, but not if the institutions are weak. We show that conservation contracts will aggravate the dependence on institutions, since the contracts generate positive externalities when districts are strong, but negative externalities when they are weak.

The papers cited above do not consider the interaction between districts. But estimates of "leakage" can be quite high, as mentioned above, and scientists have pointed out the importance of accounting for leakage when comparing various types of conservation contracts (Busch et al., 2012). In our model, the leakage is related to shifts in market shares when districts are strong, and to crime displacement when districts are weak and the extraction is illegal. There is plenty of empirical support for crime displacement, although the mechanism is not necessarily through the market. To the best of our knowledge, our model is the first to recognize that by letting a fraction of the resource be unprotected, the supply (of the harvest) increases and the price declines, thereby reducing the pressure and the enforcement cost on the part that is to be conserved. This mechanism thus adds a new perspective to the more general literatures on crime, enforcement, and inspection games.

Our second contribution is to the literature on conservation contracts. The leakage and the associated externality between the districts weaken the effectiveness, and influence the design of, conservation contracts. We thus diverge from the growing literature on how to

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8See Brollo et al. (2013), Mehlum et al. (2006), Torvik (2009), Robinson et al. (2006), Robinson et al. (2014), or the survey by van der Ploeg (2011). The value of forests can be an important driver of the resource curse (Ross, 2001).

9In contrast to the estimates in that paper, we analytically derive the optimal contract in a setting which also allows for illegal logging and protection costs.

10See Dell (2015) or Gonzalez-Navarro (2013) for recent evidence; for surveys, see or the handbook chapters by Johnson et al. (2012), Helsley (2004), or Epple and Nechyba (2004).

11For overviews, see Polinsky and Shavell (2007) and Avenhaus et al. (2002), Eeckhout et al. (2010) and Lando and Shavell (2004) also reach the conclusion that it may be optimal to monitor some places (or groups) intensively, and not at all elsewhere. The reason is, as in this paper, that enforcement must reach a certain level to have any impact. However, these papers do not take into account that by abstaining from monitoring some places, the required monitoring level declines for the places where the law is to be enforced. This effect, which we emphasize, means that there is an interior solution for the amount of area that is to be protected even when there is no budget constraint or convex effort cost. Our mechanism also differs from that in Kremer and Morcom (2000), where the regulator may want to increase the (potential) supply--not to reduce the monitoring cost, as here--but in order to reduce the incentive to poach and thus eliminate the bad equilibrium in a dynamic game with multiple equilibria (one of them being extinction and thus low supply).
design agreements for PES (Engel et al., 2008) or REDD (Kerr, 2013), which tends to focus on textbook contract-theoretic problems such as moral hazard (Gjertsen et al., 2010), private information (Chiroleu-Assouline et al., 2012; Mason, 2013; Mason and Plantinga, 2013), or observability (Delacote and Simonet, 2013). Instead, the analysis in our paper relates more to the literature on contracts in the presence of externalities. While the general theory has been outlined by Segal (1999), our model endogenizes the sign and the level of the externality, and our results are more detailed in characterizing the contract for the particular case of resource extraction. More importantly, we go further than Segal (1999) by searching for the principal’s optimal contracting partner (central vs. local governments), which is an important issue for real-world conservation contracts, and by showing how the principal’s presence influences the organizational structure among the agents (i.e., the districts). Our endogenization of the political regime is thus our third—and most intriguing—contribution.

The benefit from centralizing political power in the presence of externalities has been recognized at least since the famous decentralization theorem of Oates (1972), but our approach identifies trade-offs that are closer to those in the literature on mergers in industrial organization. (After all, Cournot competition is a special case of our model.) The standard results arise as a special case in our model, but we permit the entities to be weak rather than strong, and we emphasize how a regulatory agency (or donor) affects the decision to centralize.

3 A Theory of Conservation

This section presents a model of conservation and resource extraction in which there are many districts and a common market for the harvest. The framework is general in that the resource can be any kind of resource (for example, oil or land), the harvest can be timber or agricultural products, and the districts can be countries or villages. To fix ideas, however, we refer to the resource as forest.

To motivate the framework we start by sequentially presenting two alternative models of

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12 Harstad (2015) takes a political-economy (and game-theoretic) approach by showing when and why conservation contracts are not offered in equilibrium in a dynamic setting. That mechanism does not appear in the present framework, however.

13 Other important articles in this literature is Segal and Whinston (2003), who focus on privately observed contracts; Gomes (2005), who studies multilateral contracts; and Genicot and Ray (2006), who allow agents to coordinate (but not centralize), and show that the principal still manages to "split and rule."

14 For example, we show how the optimal reference level should generally differ from the business-as-usual level, in contrast to the traditional presumption and advice (Busch et al., 2012).

15 See the contributions in Angelsen (2008b).

16 It is well known from this literature that mergers and acquisitions can be beneficial for firms that seek monopoly power, although the actions of fringe firms must also be taken into account. In an industry of \( n \) firms, Salant et al. (1983) showed that it is not profitable for two firms to merge, since the other \( n - 2 \) firms will produce more, as a result. A merger is profitable only when it includes more than \( n/2 \) firms, according to Gaudet and Salant (1991).
conservation before we combine them. In both cases there is a regional market with \( n \geq 1 \) districts, and we let \( x_i \) be the extraction level in district \( i \in N = \{1, ..., n\} \). The aggregate harvest, \( x = \sum_{i \in N} x_i \), is sold on the common market. The larger is \( x \), the smaller is the price. In the simplest possible setting, a linear demand curve can be derived from quadratic utility functions:

\[
p = \bar{p} - ax,
\]

where \( \bar{p} \) and \( a \) are positive constants and \( p \) is the equilibrium price.

A sales-driven model. If districts are motivated by the profit generated by the sales, district \( i \)'s payoff may be represented by \( bp x_i - v_i x_i \), where \( b \) is the benefit of profit, \( p \) is the price for the harvest, and \( v_i \) is district \( i \)'s marginal opportunity value when losing the forest. For example, \( v_i \) may represent the environmental benefits which the forest provides to \( i \) or the tax or lost transfer which \( i \) experiences from more extraction. In Section 5, we will let \( v_i \equiv v + t_i \), where \( t_i \) is a tax or a transfer.

A protection-driven model. While the sales-driven model is standard, our protection-driven model is new. We now consider a setting in which districts do not extract to sell, but where they try to prevent illegal extraction. If protection is difficult, one must take into account that an illegal logger earns the price \( p \) by extracting a unit of the forest. This profit must be compared to the expected penalty, \( \theta \), which one faces when logging on that unit of the forest. The enforcement is preventive if and only if the expected penalty is larger than the benefit:

\[
\theta \geq p.
\]

We let districts set their expected penalties in advance in order to discourage extraction. In principle, the expected penalty can be increased by a larger fine or penalty, but there is a limit to how much the fine can be increased in economies with limited liabilities. To raise the expected penalty further, one must increase the monitoring probability, and this is costly. We let \( c > 0 \) denote the cost of increasing monitoring enough to increase the expected penalty by one unit. Thus, if (2) holds, it will bind: there is no reason to monitor so much that (2) holds with strict inequality. Further, if (2) does not hold, then \( \theta = 0 \): if monitoring is not preventing logging, there is no reason to monitor at all. This implies that for each unit of the forest, either the district protects the unit and ensures that (2) binds, or the district does not protect at all, and that unit of the forest will be cut.

District \( i \) has a large forest or resource stock \( X_i \), and it is allowed to monitor each unit with a different intensity. Since the optimal monitoring intensity for each unit ensures that the expected penalty is either \( p \) or 0, it follows that a part of the forest will be protected
and conserved, perhaps as a national park, while the remaining part will not be sufficiently protected and thus will eventually be cut. Since $x_i$ denotes the extraction level in district $i$, such that $X_i - x_i$ is the size of the forest that is conserved, then $i$'s payoff is $-cp(X_i - x_i) - v_ix_i$, since $\theta = p$ for the part $(X_i - x_i)$ that is conserved.\footnote{To be precise, let $S_i$ be $i$'s forest stock of size $X_i$, and let $\theta_s$ be the expected penalty when logging unit $s \in S_i$. If the forest units are divisible then $i$'s payoff is 

$$u_i = -c \int_{S_i} \theta_s ds - v_i \int_{S_i} 1_s ds,$$

where $1_s = 1$ if $\theta_s < p$ but $1_s = 0$ if $\theta_s \geq p$. Since there will be a corner solution for the optimal $\theta_s$, $u_i$ can be written as $-cp(X_i - x_i) - v_ix_i$.}

The model thus suggests that conservation policies will be "place-based" (for example, restricted to geographically limited but protected national parks), as seems to be the case in Indonesia, where "national and provincial governments zone areas of forest land to be logged" (Busch et al., 2015: 1328).

The combined model. More generally, district $i$ may benefit by the part of the resource that is extracted and sold, $x_i$, at the same time that it finds it expensive to protect the remaining part, $X_i - x_i$. When the arguments above are combined, the utility of district $i$ becomes:

$$u_i = bpx_i - cp(X_i - x_i) - v_ix_i.$$  \tag{3}$$

Below we formally define districts as "strong" if they benefit a lot from the sale ($b$ is large) while finding enforcement inexpensive ($c$ is small). We will define districts as "weak" if, instead, $b$ is small while $c$ is large. This terminology is consistent with the literature on state capacity, discussed in the Introduction.

Remark 1: Interpretations and generalizations. There are several alternative interpretations of the combined model such as it is summarized in (3). First, even if all extraction is illegal, a district may have some concern for the welfare of the loggers, in particular if they are poor and/or citizens of the district. Parameter $b$ may then represent this concern. Alternatively, parameter $b$ may reflect the probability that the government in a district captures the profit from the illegal loggers, even in the areas where the forest is not protected.\footnote{As a third interpretation, if district $i$ decides to extract $x^*_i$ units for sale in order to raise revenues, such extraction may require infrastructure and roads, which in turn may also lead to illegal logging in the amount $\alpha x^*_i$, where $\alpha > 0$ measures the amount of illegal logging when the government cuts. Such a complementarity is documented by de Sá et al. (2015). Total extraction is then $x_i = (1 + \alpha) x^*_i$ even though the fraction of the total profit, captured by the government in district $i$, is only $b \equiv 1/(1 + \alpha)$. The larger the fraction of illegal logging, the smaller $b$ is. Whatever is not cut must be protected, just as before.}

The model is simple and can easily be generalized in a number of ways. For example, we
allow for district-specific parameters $b$ and $c$ in our working paper. Furthermore, note that we have linked the districts by assuming that the harvest is sold at a common downstream market, but we could equally well assume that districts hire labor or need inputs from a common upstream market. To see this, suppose that the price of the harvest is fixed at $\hat{p}$, and consider the wage cost of the labor needed to extract. If the labor supply curve is linear in total supply, and loggers are mobile across districts, then we may write the wage as $\hat{w} + ax$, where $\hat{w}$ is a constant and $a > 0$ is the slope of the labor supply curve. Defining $p \equiv \hat{p} + \hat{w}$, we can write this model as (1)-(3). It is thus equivalent to the model described above.

**Remark 2: Nonpecuniary externalities.** Without changing the analysis, we can easily allow for cross-externalities such that district $i$ loses $\bar{v}_{-i}$ when the other districts extract. To see that our model already captures this case, suppose that $i$’s true payoff is:

$$\tilde{u}_i = bp x_i - cp \left( X_i - x_i \right) - \bar{v}_i x_i - \bar{v}_{-i} \sum_{j \in N \setminus i} x_j.$$  

We can then write the payoff as (3) if we simply define $u_i \equiv \tilde{u}_i + p\bar{v}_{-i}/a$ while $v_i \equiv \bar{v}_i - \bar{v}_{-i}$ and $X_i \equiv X_i - \bar{v}_{-i}/ca$. Thus, a larger cross-externality can be captured by considering a reduction in $v_i$ and $X_i$ in the model described above.

4 Conservation and Political Regimes

Based on the combined model above, in which resource extraction can be sales-driven or protection-driven, this section discusses the equilibrium amount of extraction and conservation. In particular, we will focus on how equilibrium extraction depends on whether districts are weak or strong and the number of districts; discuss when one district benefits or loses if other districts conserve more; and investigate the effect of political centralization. These results are interesting in themselves, and they are also necessary to describe before we analyze conservation contracts in the next section and endogenous regimes in Section 6.

4.1 The Equilibrium

Let $X = \sum_{i \in N} X_i$ be the total size of the resource, while $\bar{v} = \sum_{i \in N} v_i/n$ is the average $v_i$. It is straightforward to derive the market equilibrium since each $u_i$ is quadratic and concave in $x_i$, given (1).

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19 Harstad and Mideksa (2015). See also footnote 21, below, explaining why the additional insight does not justify the added complexity.
Proposition 1. In equilibrium, extraction is given by:

\[ x_i = \frac{(b + c)p + acn_i - ac\sum_{j\in N\setminus i} X_j - n v_i + \sum_{j\in N\setminus i} v_j}{a(b + c)(n + 1)} \]  \( \Rightarrow \)  \( (4) \)  

\[ x = \frac{n}{n + 1} \frac{p}{a} + \frac{acX - n\bar{v}}{a(b + c)(n + 1)} \]  \( \Rightarrow \)  \( (5) \)  

\[ p = \frac{n}{n + 1} - \frac{acX - n\bar{v}}{(b + c)(n + 1)}. \]  \( (6) \)  

We will consider only interior solutions such that the right-hand side of (4) is assumed to be positive but less than \( X_i \) for every \( i \). If the right-hand side were instead negative (or larger than \( X_i \)), the equilibrium would be \( x_i = 0 \) (or \( x_i = X_i \)).

Quite intuitively, extraction is smaller if the districts’ opportunity values are high; and \( p \) is then also high. However, aggregate extraction \( x \) is larger if demand is large (\( \bar{p}/a \) large) or the protection cost \( c \) is large. If the benefit of sales, \( b \), is large, then extraction increases in the typical sales-driven model (where \( c \) is large), but extraction is instead decreasing in \( b \) if the protection cost is large: the reason is that when protection is expensive, extraction is so large that the equilibrium price is low. If the weight on profit increases, equilibrium extraction will be reduced to raise the price. Thus, if districts get stronger in that \( b \) increases, they extract more if and only if they are also strong in that the protection cost is small.

Corollary 1. If the weight on profit (\( b \)) increases, then \( x \) increases if the enforcement cost is small, but \( x \) decreases if the enforcement cost is large:

\[ \frac{\partial x}{\partial b} > 0 \text{ if and only if } c < \frac{n\bar{v}}{aX}. \]

Note from (4) that a district \( i \) extracts more if its own resource stock is large, since a larger \( x \) reduces \( p \) and thus the protection cost for the (large) remaining amount. However, if the other districts are large or have small opportunity costs, then these other districts will extract a lot and this reduces the price. When \( p \) is small, it is both less profitable to sell, and less expensive for \( i \) to protect its resource. For both reasons, district \( i \) conserves more when \( X_j \) is large or \( v_j \) is small, for \( j \neq i \).

4.2 Pecuniary Externalities

Having solved for the equilibrium, we can be precise about when districts benefit from a high price. When we take the partial derivative of (3) with respect to \( p \), and substitute with (4),
we get:
\[
\frac{\partial u_i}{\partial p} = \frac{e_i}{a(n+1)} \text{ where } e_i \equiv b\overline{p} - c(aX - \overline{p}) - nv_i + \sum_{j \in N \setminus i} v_j. \tag{7}
\]

With this, it is natural to define our labels in the following way.

**Definition.** Districts are strong and extraction is sales-driven if districts benefit from a high price (i.e., \(e_i > 0\)). Districts are weak and extraction is protection-driven if districts benefit from a low price (i.e., \(e_i < 0\)).

With this definition, districts are strong or, equivalently, extraction is sales-driven if \(e_i > 0\), which holds not only when the benefit from profit \((b)\) is large, but also when the market size \((\overline{p}/a)\) is large compared to the total resource stock, and when protecting the resource has small costs \((c)\) or low value \((v_i)\). Note that we always have \(e_i > 0\) in the standard Cournot model (where \(c = 0\)) when \(x_i > 0\). In contrast, we say that districts are weak and extraction is protection-driven when districts benefit from a low price, since costly monitoring must increase accordingly. This requires that \(e_i < 0\), which always holds in the model of illegal extraction (when \(b = 0\) and \(v_i = v_j\)).

Since the price is endogenous and increases when the neighbors conserve, \(e_i\) can also be referred to as the intra-district (pecuniary) externality from conservation.

**Proposition 2.** (i) District \(i\) benefits when another district conserves if and only if \(e_i > 0\):

\[
\frac{\partial u_i}{\partial (-x_j)} = \frac{e_i}{n+1}.
\]

(ii) At the equilibrium conservation levels, we also have:

\[
u_i = \frac{1}{a(b+c)} \left[ \left( \frac{e_i}{n+1} \right)^2 - acv_i X_i \right]. \tag{8}\]

**Corollary 2.** From (8) and the definition of \(e_i\), we get:

\[
\text{sign} \frac{\partial u_i}{\partial \overline{p}} = \text{sign} \frac{\partial u_i}{\partial v_j} = -\text{sign} \frac{\partial u_i}{\partial X_j} = \text{sign} e_i. \tag{9}\]

Corollary 2 shows that the sign of \(e_i\) is important when evaluating several changes. If the market size \(\overline{p}\) increases, the price is higher; a high price is beneficial in a sales-driven model where \(e_i > 0\), but not when districts are weak and find protection costly. If a district \(j \neq i\) values conservation more, or if \(j\)'s resource stock is smaller, then \(j\) is expected to extract less. District \(i\)'s utility will then increase if and only if \(e_i > 0\).
Remark 3: Nonpecuniary externalities. As mentioned in Remark 2, nonpecuniary externalities can be accounted for by simply redefining some parameters. If \( i \) loses \( \tilde{e}_i \) when other districts extract, we still have \( \frac{\partial u_i}{\partial \bar{p}} = e_i/a \ (n + 1) \) and the nonpecuniary externality is simply added to \( e_i \), which can be written as:

\[
e_i = b\bar{p} - c \left( a\tilde{X} - \bar{p} \right) - n\tilde{v}_i + \sum_{j \in N \setminus i} \tilde{v}_j + n\tilde{v}_{-i}.
\]

(10)

4.3 The Political Regime

The sign of \( e_i \) is also important for district \( i \)'s strategy. If \( e_i > 0 \), district \( i \) prefers a high price, and thus \( i \) has an incentive to keep the price high by strategically conserving more. If \( e_i < 0 \), district \( i \) has an incentive to extract more to keep the price and thus the pressure low.

These strategic incentives are particularly important for a large district which influences the price more by a given change in \( x_i/X_i \). It thus follows that while large districts conserve a larger fraction of their resource in a sales-driven model (in order to keep \( p \) high), they conserve a smaller fraction when extraction is protection-driven (in order to reduce \( p \) and thus the pressure on the resource). This can be seen by inserting (7) into (4) to get:

\[
\frac{x_i}{X_i} = \frac{ac}{a \ (b + c)} + \frac{e_i/X_i}{a \ (b + c) \ (n + 1)}.
\]

Corollary 3. A larger district \( i \) conserves a larger fraction of its resource if and only if \( e_i > 0 \):

\[
\frac{\partial x_i}{\partial X_i} = \frac{-e_i/X_i^2}{a \ (b + c) \ (n + 1)}.
\]

The effect of the number of districts, \( n \), is equally ambiguous and interesting. In a sales-driven model, it is well known from Cournot games that if the number of sellers increases, then so does the aggregate quantity supplied, while the price declines. We should thus expect \( \partial x/\partial n > 0 \) in a sales-driven model. With protection-driven extraction, however, districts conserve less when they take into account the fact that the pressure on the resource weakens as a consequence. It is for this reason that large districts conserve less. By inserting (7) into (5), we can see that \( \partial x/\partial n < 0 \) if and only if \( \bar{v} < 0 \):

\[
x = \frac{cX}{b + c} + \frac{n\bar{v}}{a \ (b + c) \ (n + 1)}, \text{ where } \bar{v} \equiv \frac{1}{n} \sum_{i \in N} e_i = \frac{(b + c)\bar{p} - acX - \bar{v}}{n}.
\]

(11)

---

20Just as in Remark 2, if \( \tilde{X} \) is the actual forest size, \( \tilde{v}_i \) is \( i \)'s actual cost of losing its forest while \( \tilde{v}_{-i} \) is \( i \)'s direct loss when \( j \) cuts, then our analysis continues to hold if we define \( v_i \equiv \tilde{v}_i - \tilde{v}_{-i} \) and \( X_i \equiv \tilde{X}_i - \tilde{v}_{-i}/ca \). By substituting these parameters into (7), we get (10).
The number of districts is therefore important. If decision-making authority is centralized, the number of relevant governments \( n \) declines while the aggregate resource \( X \) remains unchanged. To isolate this effect, we assume \( b \) and \( c \) stay unchanged after a regime change.

**Proposition 3.** Fix \( X \) and \( \overline{v} \). Centralization (implying a smaller \( n \)) leads to more conservation if districts are strong \( (\overline{e} > 0) \) but less if districts are weak \( (\overline{e} < 0) \).

The proposition holds whether it is only a couple of districts that centralize authority to a common central authority, or all the \( n \) districts that centralize power to a single government. If authority is centralized to a single central government, \( C \), then \( n = 1 \) and (11) becomes:

\[
x_C = \frac{cX}{b + c} + \frac{\overline{e}}{2a (b + c)} = \frac{p (b + c) + acX - \overline{e}}{2a (b + c)}.
\]

(12)

### 5 Conservation Contracts

The previous section derived equilibrium conservation as a function of the parameters in the model. In this section, we further assume that every district has a utility function that is linear and additive in the transfer \( \tau_i \in \mathbb{R} \). We have already suggested that district \( i \)'s opportunity cost of extraction, \( v_i \), may in part come from lost subsidies or a higher tax on extraction:

\[
v_i = v + t_i,
\]

where \( t_i \in \mathbb{R} \) can represent an extraction tax, so that the transfer to \( i \) would be \( \tau_i = -t_i x_i \).

Since we now let \( v \) be common for the districts,\(^{21}\) the externality (when \( t_i = 0 \)) will be:

\[
\overline{e} \equiv (b + c) p - acX - v.
\]

Given (13), (4) shows that \( x_i \) is a function of \( t = (t_1, \ldots, t_n) \):

\[
x_i(t) = \frac{e + ac (n + 1) X_i - t_i n + \sum_{j \neq i} t_j}{a (b + c) (n + 1)}.
\]

(14)

Thus, \( u_i \) can be written as a function of \( x(t) = (x_1(t), \ldots, x_n(t)) \). From equations (1)-(3):

\[
u_i^0(x(t)) = bpx_i(t) - cp (X_i - x_i(t)) - vx_i(t),
\]

\(^{21}\)If, instead, the exogenous parts of \( v \) differed for some pair of districts, then a central authority maximizing the sum of utilities would prefer a corner solution where everything is conserved in one district or nothing in the other. Such a corner solution would hinge on the linearity assumptions in our model and is thus uninteresting to emphasize. See, however, Section 6 in Harstad and Mideksa (2015), where we fix the political regime and allow for heterogeneity in the \( v \)'s, the \( b \)'s, and the \( c \)'s.
where superscript 0 just indicates that the cost of $t_i$ is not taken into account in the definition of $u_i^0$. With $\tau_i = -t_i x_i$, $i$’s actual payoff is just as in (3):

$$u_i^0(x(t)) + \tau_i = bpx_i(t) - cp(X_i - x_i(t)) - (v + t_i)x_i(t).$$

In this section we study contracts between the districts and a principal or a "donor" $D$. We assume that $D$ benefits from conservation and that $u_D = -dx$, where $d > 0$ measures the damage $D$ faces from the districts’ extraction. Also $D$ has a quasi-linear function for the payoff $u_D + \tau_D$, where $\tau_D$ is the transfer to $D$. By budget balance, $\tau_D = -\sum_{i \in N} \tau_i$. In the following, we will derive (1) the first-best (Pareto-optimal) allocation as well as the equilibrium contract between (2) $D$ and a central government $C$ and (3) $D$ and $m \leq n$ districts. Section 6 studies when $D$ prefers to contract with $C$ rather than the districts, and it shows how the equilibrium regime is influenced by the presence of the donor. (The technical Appendix B discusses robustness of the contract.)

### 5.1 The First Best

Since we have assumed transferable utilities and $n + 1$ players, any Pareto optimal allocation $x = (x_1, ..., x_n)$ must maximize $u_D(x) + \sum_{i \in N} u_i^0(x)$. Pareto optimality cannot pin down the transfers or even the allocation of $x_i$’s when $x$ is given and $v$ is the same for every district, but the Pareto-optimal $x$ is unique.

**Proposition 4.** (i) The first-best extraction level is given by:

$$x_{FB} = \frac{cX}{b + c} - \frac{d - e}{2a(b + c)}. \quad (15)$$

(ii) The first-best $x_{FB}$ is implemented by the decentralized equilibrium if and only if:

$$\frac{\sum_{i \in N} t_i}{n} = t_{FB} \equiv \left(\frac{n + 1}{2n}\right)d + \left(\frac{n - 1}{2n}\right)e. \quad (16)$$

Part (i) shows that the expression for $x_{FB}$ equals the expression for $x_C$ if simply $v$ in (12) is replaced by $v + d$. Part (ii) of the proposition follows from combining (5), (13), and (15). It states that the first-best tax or (subsidy) rate $t_{FB}$ is a weighted average of the two externalities $e$ and $d$. To understand this, note that even when $d = 0$, $t_i > 0$ is optimal if and only if other districts benefit when $i$ conserves more. This would be the case when districts are strong and

\[\text{For simplicity, we ignore the possibility that the donor’s transfer arrives later than the revenues from logging. If the district needs money today and credit markets are imperfect, conservation contracts could be ineffective (Jayachandran, 2013).}\]
extraction sales-driven. When districts are weak and extraction protection-driven, then \( t_i < 0 \) would be optimal instead.\(^{23}\)

When decision-making power is centralized to a single authority, then \( n = 1 \) and the Pigou tax is standard.

**Corollary 4.** Under centralization, the first best is implemented simply by \( t_C = d \). Facing \( t_C = d \), C will induce its districts to select \( x_{FB} \) by, for example \( \bar{t} = t_{FB} \).

The second part of the corollary is just pointing out that since C maximizes the sum of the districts’ payoffs, it will tax extraction according to (16) if just \( d \) is replaced by \( t_C \). We thus have a formula for how C can implement its desired policy for any given \( t_C \):

\[
\bar{t}(t_C) = \left( \frac{n+1}{2n} \right) t_C + \left( \frac{n-1}{2n} \right) e.
\]

### 5.2 Contracts under Centralization

While Proposition 3 describes the first best, we now derive the equilibrium contract if D can make a take-it-or-leave-it offer. We assume the extraction level is contractible so that the transfer from D can be a function of \( x \). Since there is a deterministic relationship between \( x \) and the contract, it suffices to consider linear conservation contracts of the type observed in reality (see the remark at the end of this section). If D contracts with C, this means:

\[
\tau_C = \max \{0, (\bar{x}_C - x) t_C \},
\]

where \( \bar{x}_C \) is a baseline deforestation level. The contract, which consists of the pair \((t_C, \bar{x}_C)\), implies that C receives \( t_C \) dollars for every unit by which the actual extraction \( x \) is reduced relative to the baseline level \( \bar{x}_C \). If \( x \geq \bar{x}_C \), no payment is taking place. When \( x < \bar{x}_C \), the transfer can be written as \( \tau_C = t_C \bar{x}_C - t_C x \), with the last term being equivalent to a tax \( t_C \), while the first term is equivalent to a lump-sum payment.

If \( x < \bar{x}_C \), then C’s payoff is \( u_C^0 (x_C (t_C)) + t_C (\bar{x}_C - x_C (t_C)) \), where \( x_C (t_C) \) recognizes that \( x_C \) is a function of \( t_C \). This function is given by (12), taking into account that \( \bar{v} = v + t_C \). Note that \( x_C \) is then not a function of the baseline \( \bar{x}_C \), which confirms that the \( t_C \bar{x}_C \)-part of the transfer is like a lump sum.

\(^{23}\)As a remark on the details, note that the levels of \( \partial u_i / \partial (-x_j) \) and \( e_i \) depend on \( t_i \). Given (7) and (13), \( e_i \) increases in \( t_j \) but decreases in \( t_i \) and in a common tax \( t \). The Pigou tax that internalizes all externalities is thus

\[
t_i = \sum_{j \in N \setminus i} \frac{\partial u_i}{\partial (-x_j)} + d = (n - 1) \frac{e - n (v + t_i) + \sum_{j \in N \setminus i} t_j}{n + 1} + d,
\]

which can be written as (16).
Since D’s objective is to maximize

$$u_D - t_C \cdot (\pi_C - x),$$

(17)

D would prefer to reduce the total transfer \(t_C\) by reducing the baseline \(\pi_C\). However, D must ensure that the following incentive constraint for C is satisfied:

$$u_C^0 (x_C (t_C)) + t_C \cdot (\pi_C - x_C (t_C)) \geq u_C^0 (\hat{x}_C) \forall \hat{x}_C > \pi_C. \quad (IC_C)$$

That is, C’s payoff in equilibrium cannot be smaller than what C could achieve by optimizing as if there were no transfer. In equilibrium, \(\pi_C\) will be reduced by D until \((IC_C)\) binds with equality.

**Proposition 5.** When D contracts with C, the contract \((t_C, \pi_C)\) is:

$$t_C = d,$$

$$\pi_C = x_C (0) - \frac{d}{4a (b + c)}. \quad (18)$$

Thus, the optimal rate \(t_C = d\) is very simple and independent of the parameters in the model, whether the country is weak or strong, or whether extraction is sales-driven or protection-driven. To derive the result, just substitute \((IC_C)\) into (17), and note that D is induced to maximize the sum \(u_C + u_D\).

**Corollary 5.** When D contracts with C, the outcome is first best. C faces \(t_C = d\) and induces its districts to select \(x_{FB}\) by setting the average tax equal to \(t_{FB}\).

The baseline \(\pi_C\) will be set such that \((IC_C)\) binds and C is exactly indifferent between choosing \(x_C (t_C)\) and \(x_C (0)\). The indifference means that the benchmark \(\pi_C\) will be strictly smaller than the business-as-usual level \(x_C (0)\), as illustrated by (18), since otherwise C would strictly benefit from the contract. If \(\pi_C\) were not dictated by D, but instead had to equal some historical or business-as-usual level, then D would prefer some other \(t_C \neq d\), and the first best would not be implemented. This result disproves the typical presumption that the reference level should equal the business-as-usual level.\(^{24}\)

\(^{24}\) See, for example, Busch et al. (2012) or Angelsen (2008a). The latter contribution also discusses why the baseline may be smaller than the business-as-usual (or historical) deforestation level, since this reduces the amount that needs to be paid. This conclusion by Angelsen (2008a) is invalid if there are multiple districts, we show below (Proposition 6).
5.3 Contracts under Decentralization

We now return to the model in which \( n \) districts act noncooperatively when deciding on the \( x_i \)'s. As explained below, it suffices to consider actual conservation contracts of the form:

\[
\tau_i = \max \{0, (\bar{x}_i - x_i) t_i \}, \tag{19}
\]

where \( \bar{x}_i \) is the baseline for district \( i \). Suppose \( D \) unilaterally designs the contract \((t_i, \bar{x}_i)\) for every \( i \in M \subseteq N \), where \( m = |M| \leq n \). Even if \( D \) would like to contract with all \( n \) districts, this may be unfeasible for exogenous (or political) reasons.

Just as under centralization, \( D \) must ensure that a district is no worse off in equilibrium where \( x_i < \bar{x}_i \) than the district could be by ignoring the contract and picking any other extraction level \( \bar{x}_i > x_i \):

\[
u_i^0(x(t)) + t_i \cdot (\bar{x}_i - x_i) \geq u_i^0(\bar{x}_i, x_{-i}(t)) \forall \bar{x}_i > x_i. \tag{IC_i}
\]

The problem for \( D \) is to select the \( m \) pairs \((t_i, \bar{x}_i)\) in order to maximize \( u_D - \sum_{i \in M} t_i \cdot (\bar{x}_i - x_i) \) subject to the \( m \) incentive constraints.

**Proposition 6.** Suppose \( D \) contracts with \( m \leq n \) districts. The optimal contract for \( D \) is:

\[
t_i = \frac{2}{n+1} d, \tag{20}
\]

\[
\bar{x}_i = x_i(0) + \frac{4m - 3(n + 1)}{4a(b + c)(n + 1)} t.
\]

Naturally, when there is only one district \((m = n = 1)\), Proposition 6 coincides with Proposition 5. With \( n > 1 \) districts, however, contracting with district \( i \) means that \( x_i \) will decrease but every other \( x_j \) will increase: In fact, (14) shows that for every unit by which \( x_i \) is reduced, \( x \) is reduced by only \( 1/n \) units. This ratio makes it costly for \( D \) to reduce extraction when \( n \) is large, and the optimal contract is weakened. Since the ratio is independent of the other parameters in the model, so is the rate \( t \).

Similarly, \( x_i \) will increase when \( D \) contracts with several other districts. Thus, the larger is \( m \), the larger must the baseline be for the contract to remain relevant. While contracts with \( i \) increases \( j \)'s extraction level, the effect on the \( j \)'s payoffs will depend on the externality \( e \). If \( e \) is large, \( j \) benefits when \( D \) contracts with \( i \neq j \); \( D \) is unable to cash in on this benefit, since the contract with \( i \) increases \( j \)'s payoff also at the threat point when \( j \) ignores \( D \)'s contract. It is thus intuitive that \( D \) will offer contracts to \( i \) that are too weak relative to the first best
when the externality $e$ is large.

If instead $e$ is small and negative, then $j$ loses when $D$ contracts with $i$. However, $D$ does not need to compensate $j$ for this loss, since $j$ loses also at the threat point and when $j$ ignores a contract offered by $D$. Thus, when logging is mainly illegal, $D$ offers contracts that are too strong compared to the first best.

**Corollary 6.** At the equilibrium contracts, the conservation level is too large compared to the first best if and only if districts are weak ($e/d$ is small):

$$x < x_{FB} \iff \frac{\sum_{i \in N} t_i}{n} > t_{FB} \iff \frac{e}{d} < -\frac{(n + 1)^2 - 4m}{n^2 - 1}.$$ 

**Remark 4: General contracts and participation constraints.** Appendix B derives other interesting implications for the contract:

1. More general (nonlinear or multilateral) contracts cannot achieve better outcomes for $D$ than the above linear bilateral contracts.

2. If $D$ contracts with district $i \in N$, the other districts extract more and this harms $i$ if $e$ is large. Thus, $i$ may want to publicly reject the contract and pledge that it will not accept any payments from $D$. If such a pledge is credible, $D$ needs to satisfy $i$’s participation constraint in addition to the incentive constraint. The participation constraint will bind when districts are strong ($e$ large), and to relax it, $D$ will weaken the contract (so, $\partial t_i / \partial e < 0$). This contrasts the first best ($\partial t_{FB} / \partial e > 0$) and reinforces Corollary 6 in that the contract is too weak when $e$ is large.

3. The participation constraint can be relaxed by multilateral or nonlinear contracts. Thus, existing contracts (19) are suboptimal if extraction is sales-driven and districts can commit to not accept payments.

Since the participation (but not the incentive) constraint can be relaxed by more general contracts, we can always implement the outcome described by Proposition 6. For this reason, we have chosen to relegate (1)-(3) to Appendix B and instead emphasize the effects on and of political institutions. [We are happy to skip Appendix B to keep the paper short, or to include the material here to strengthen our contribution to contracts.]

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When the participation constraint binds, the equilibrium contract is:

$$t = \frac{(n + 1) d - (n - 1) e}{2 + 2m (n - 1)} \quad \text{and} \quad x_i = x_i (0) + \frac{1}{a (b + e)} \left[ \frac{n - 1}{(n + 1)^2} e + \frac{2n (m - 1) - n^2}{(n + 1)^2} t \right].$$
6 Endogenous Regimes

Section 5.2 showed that centralization was first best when the donor could offer conservation contracts, while Section 5.3 showed that decentralized contracts were generically not Pareto optimal. Both sections assumed that the donor contracted with certain districts and governments, and we took their numbers and authority levels to be exogenously given. In some cases, the donor may be able to decide whether it wants to contract with a set of districts independently, or whether it instead wants to contract with their common central government. In other cases, the districts may be capable of centralizing authority, but the incentive to do so may change when the donor is present. A regime change, in turn, may influence conservation. This section (1) studies when the donor would prefer to contract with districts rather than central authorities, (2) endogenizes the political regime and shows when the presence of the donor influences regime change, and (3) describes when the induced regime change increases extraction by more than the contracts themselves reduce it. In the latter case, the presence of the donor reduces conservation.

As a start, consider a subset \( L \subseteq M \) containing \( l \equiv |L| \) districts. If these districts centralize authority, then \( l, m, \) and \( n \) all decrease by the same number, denoted by \( \Delta \). If \( L \) centralizes to a single government, then \( \Delta = l - 1 \), but we do not require this. We assume that such a regime change does not influence the forest areas over which \( D \) can contract. Hence, \( D \) contracts with \( m - \Delta \) governments after the regime change, while the number of districts without a contract stays unchanged at \( n - m \).

We say that \( L \) is "large" (relative to \( N \)) if:

\[
\epsilon_L \equiv 1 - \frac{l}{n+1} - \frac{l - \Delta}{n - \Delta + 1} < 0. \tag{21}
\]

That is, for \( L \) to be large, it is necessary that \( L \) contains a majority of the decision-making districts before centralization \( (l > (n+1)/2) \), and it is sufficient that \( L \) contains a majority after decentralization \( (l - \Delta > (n - \Delta +1)/2) \). If \( L \) is not large, we say that \( L \) is "small."

Our first observation concerns the effect on conservation.

**Proposition 7.** If \( L \subseteq M \) centralizes, \( x \) decreases if and only if \( e/d \) is large or \( M \) is large, i.e., if:

\[
\frac{e}{d} \geq 2 \epsilon_M = 2 \left( 1 - \frac{m}{n+1} - \frac{m - \Delta}{n - \Delta + 1} \right).
\]

If \( M \) is large (say, \( m = n \)), then we know from the earlier intuition that centralization reduces \( x \) when \( e/d \) is large. If \( M \) is small, however, a large number \( (n - m) \) of other districts...
tricts will increase $x$ when $M$ reduces $x$, and thus the condition becomes harder to satisfy. Proposition 7 generalizes Proposition 3 (for the case in which there is no contract, $d = 0$).

### 6.1 Selecting Contractors

This subsection studies when the donor would prefer contracting with a central government rather than with local governments. If a central government $C$ is already active and regulating the local governments, then $C$ can always undo D’s offers to the districts; decentralized contracts would then not be an option for D. If the central government is absent or passive, however, then D may evaluate whether it should contract with the districts or instead propose a contract to the union of some districts. The latter option may require central authorities to be activated or created.

As we have already noted, when districts are strong and extraction sales-driven, then a district benefits if the others conserve more, and thus also if the others are offered conservation contracts. These positive externalities are internalized by a benevolent central government maximizing the sum of utilities. When positive externalities are appreciated by the contracting partner, D can extract more of the districts’ surplus (by reducing the baseline). Thus, if $e$ is large, D benefits when authority is centralized.

If instead the externality $e$ is small, as when districts are weak and extraction is protection-driven, the argument is reversed. A district then experiences negative externalities when others conserve or sign conservation contracts with D. Negative externalities will be taken into account by central authorities, who will thus reject the contract unless it involves larger transfers. In this case, therefore, D benefits from decentralized contracts. This holds even when the first best requires centralization.

**Proposition 8.** Decentralized contracts are preferred by D if and only if $e/d$ is small or $M$ is small:

$$\frac{e}{d} \leq \frac{\varepsilon M}{n} = 1 - \frac{m}{n + 1} - \frac{m - \Delta}{n - \Delta + 1}.$$  

The donor is more likely to prefer decentralized contracts when $M$ is small relative to $N$, since the other districts will, as a consequence, extract less when $e$ is large. This result also implies that there is a unique number $m$ that maximizes D’s payoff (i.e., the second-order conditions w.r.t. $m$ and $\Delta$ hold).

A comparison to Proposition 7 is interesting. When $M$ is large, $2\varepsilon_M < \varepsilon_M < 0$. Thus, when $e/d \in (2\varepsilon_M, \varepsilon_M)$, D finds having decentralized contracts to be less expensive, even if centralization would have increased conservation. When $M$ is instead small, $0 < \varepsilon_M < 2\varepsilon_M$. In this case, when $e/d \in (\varepsilon_M, 2\varepsilon_M)$, D finds having centralized contracts to be less expensive,
even if decentralization would have increased conservation. When $e/d$ is outside these intervals, D prefers the regime that maximizes conservation.

**Corollary 7.** (i) If $M$ is large, D always prefers decentralized contracts if this reduces $x$, but the converse is not true.

(ii) If $M$ is small, D always prefers centralized contracts if this reduces $x$, but the converse is not true.

### 6.2 Equilibrium Regime

While the previous subsection analyzed the regime preferred by the donor, we now study the preferences of the districts and derive the equilibrium regime. In particular, we consider the subset $L \subseteq M$ and investigate when the sum these districts’ payoffs is larger if they centralize and lower the number of districts to $l-\Delta$. If it is, we say that $L$ prefers centralization.

To understand the following result, consider first the case without the donor. If $L = N$, we know that the sum of payoffs is highest under centralization, since externalities make decentralization inefficient. It is thus intuitive that if $L$ is large, $L$ will prefer centralization in the absence of D. If $L$ is small, however, $L$ may pay more attention to what the other districts will do when $L$ decentralizes. If $e > 0$ ($e < 0$), $L$ will conserve less (more) if it decentralizes, and, in response, the other districts will conserve more (less). The effect of the others’ actions is beneficial to $L$ (regardless of $e$). Since the number of other districts is large when $L$ is small, a small $L$ prefers to decentralize in the absence of D. This is confirmed in the following result for the special case where $d \rightarrow 0 \Rightarrow |e/d| \rightarrow \infty$.

**Proposition 9.** (i) If $L$ is large, $L$ prefers decentralization if and only if $e/d \in [\hat{\xi}_L, \bar{\xi}_L]$, where $\bar{\xi}_L > \hat{\xi}_L > \xi_M > 2\xi_M < 0$.

(ii) If $L$ is small, $L$ prefers centralization if and only if $e/d \in [\bar{\xi}_L, \hat{\xi}_L]$, where $\bar{\xi}_L < \hat{\xi}_L < \xi_M$.

The thresholds are given by:

$$
\hat{\xi}_L \equiv 1 - \frac{2(m - \Delta)}{n - \Delta + 1} - \frac{2m - 2\Delta}{n - \Delta + 1}, \quad \bar{\xi}_L \equiv 1 - \frac{2(m - \Delta)}{n - \Delta + 1} + \frac{2m - 2\Delta}{n - \Delta + 1}.
$$

Part (i) shows that a large $L$ may prefer to decentralize authority in the presence of an important D (i.e., unless $d$ is very small). As revealed by the inequality $\hat{\xi}_L > \xi_M$, this will be the case only when $e$ is so large that D would have preferred centralized contracts. Thus, $L$
decentralizes only when this harms D.

Part (ii) similarly states that \( \hat{\epsilon}_L < \epsilon_M \). Taken together with Proposition 8, this implies that whenever a small \( L \) prefers to centralize authority, then D would instead have preferred decentralized contracts. It may come as no surprise that D and \( L \) have conflicting preferences, given that the regime influences the transfers from D.

**Corollary 8.** (i) Suppose \( L \) is large. If \( L \) prefers decentralization, D prefers centralized contracts. If D prefers decentralized contracts, L prefers centralization.  
(ii) Suppose \( L \) is small. If \( L \) prefers centralization, D prefers decentralized contracts. If D prefers centralized contracts, L prefers decentralization.

Another corollary of Proposition 9(i) can be drawn from the statement \( \hat{\epsilon}_L > 2\epsilon_M \). Together with Proposition 7, this implies that whenever a large \( L \) prefers decentralization, then decentralization reduces conservation. A related fact can be derived from part (ii) for the special case in which \( L = M \). In that case, we know that for a small \( L \), \( \epsilon_M > 0 \) and thus \( \hat{\epsilon}_L < \epsilon_M < 2\epsilon_M \). Hence, whenever a small \( L = M \) prefers centralization, centralization reduces conservation.

**Corollary 9.** (i) Suppose \( L \) is large. If \( L \) prefers decentralization, decentralization increases extraction. If decentralization reduces extraction, L prefers centralization.  
(ii) Suppose \( L=M \) is small. If \( L \) prefers centralization, centralization increases extraction. If centralization reduces extraction, L prefers decentralization.

### 6.3 The Donor’s Influence on Conservation

In the absence of the donor (or when \( d \to 0 \)), Proposition 9 states that a large \( L \) would centralize while a small \( L \) would decentralize. Corollary 8 states further that if a large \( L \) decentralizes, D would have preferred that it didn’t; and if a small \( L \) centralizes, D would have preferred that it didn’t. We can summarize these observations as follows.

**Corollary 10.** The presence of the donor may induce a regime change. If so, the induced regime change always harms the donor.

Corollary 9 states further that if \( L \) is large, or if \( L \) and \( M \) are small, then the induced regime change leads to less conservation. Based on these findings, one may question whether the reduced conservation levels following regime change can outweigh the effect of the contracts offered by D. If so, the very presence of D leads to regime change and so much more extraction that a larger part of the resource would have been conserved if D, as well as D’s contracts,
had been absent. In this case, D’s presence does more harm than good and D would have preferred to commit to abstaining from offering contracts, if such a commitment were feasible.

**Proposition 10.** (i) Suppose \( L \) is large. If \( e/d < \bar{e}_L \), the presence of D induces decentralization and, despite the contracts, \( x \) increases when the following holds:

\[
\frac{e}{d} > \bar{e}_L = \frac{2m (n - \Delta + 1)}{(n + 1) \Delta}.
\]

(ii) Suppose \( L \) is small. If \( e/d \in [\bar{e}_L, \tau_L] \), the presence of D induces centralization and, when also \( e/d < -\tau_L \), \( x \) increases, despite the contracts.

Consider an example with two districts (Figure 1). Decentralized contracts are preferred by D in the shaded area, where \( e/d < \xi_M = -1/6 \approx -0.17 \), even though decentralization reduces conservation when \( e/d > 2\xi_M = -1/3 \) (where the shaded area has downward-sloping lines). The districts, however, prefer decentralization only when they are stronger and \( e/d \in (\bar{e}_L, \tau_L) \approx (-0.16, 5.5) \), i.e., in the dotted area. Furthermore, note that \( \bar{e}_L = 8/3 \in (\bar{e}_L, \tau_L) \).

Thus, for every \( e/d \in (8/3, 5.5) \), which corresponds to the colored and dotted area, the presence of D motivates the districts to decentralize and the accompanying increase in \( x \) outweighs the effect of the contracts.
7 Conclusions and Policy Lessons

This paper presents a novel, tractable model of conservation. We allow for many districts and recognize that since extracting some of the resource increases the harvest supply, it decreases the price and the monitoring costs for the part that is to be conserved. The externality from one district’s conservation on others can be positive or negative, depending on state capacities and the size of the resource stock. The model can be used to study various types of resources and alternative motivations for extractions, but it is motivated in particular by deforestation in the tropics.

The analysis generates several policy lessons, such as how decentralization of authority influences conservation. If districts are "strong" and extraction is sales-driven, then districts extract too much since they do not internalize the effect on other districts’ profit. A transfer of authority from the local to the federal level will then lead to more conservation and less extraction. If districts are "weak" and extraction is driven by the high cost of protection, then districts might conserve too much since protection in one district can increase the pressure to extract in neighboring districts. In this case, centralizing authority will reduce conservation and increase extraction. These results may also help to explain the mixed empirical evidence: as discussed in the Introduction, decentralization has increased deforestation in Indonesia, while reducing it in other areas, such as the Himalayas.

We employ the model to analyze how the optimal conservation contract depends on local institutions and the drivers of extraction. Under centralization to a single government, simple Pigou-like contracts are optimal and first best. With several independent districts, however, the equilibrium contract can lead to too much conservation when districts are weak and too little when they are strong. We also show that the donor benefits from contracting with districts if these are weak and extraction is illegal, but with central authorities if districts are strong and extraction is sales-driven. These policy lessons are important when designing real-world conservation contracts.

Policy makers should also be alert to our finding that institutions may be altered by the donor’s presence. The districts may prefer to centralize authority if they are weak, and to decentralize if they are strong. A regime change that is induced by the donor’s presence (whether this means decentralization or centralization) always harms the donor. Furthermore, donor-induced regime change is likely to increase extraction, and this increase can be so large that it outweighs the effect of the contracts themselves. In these cases, it is essential that the donor builds a reputation for contracting only with certain authority levels.

Our workhorse model is tractable and can be extended in several directions. Other scholars
may want to take advantage of this tractability, since the benchmark results we have derived rely on a number of limiting assumptions. In particular, future research should allow the resource (whether renewable or exhaustible) to be extracted over time in a dynamic setting, the functional forms ought to be generalized, parameters might be privately known, and the outcome may also be stochastic. Allowing for these and other generalizations is necessary to further improve our understanding of how the world’s natural resources can be conserved.
References


8 Appendix A: Proofs

Proof of Proposition 1. 
Note that the first-order condition when maximizing (3) w.r.t. $x_i$ and subject to (1) gives:

$$x_i = \frac{p}{a} + \frac{caX_i - v_i}{a(b + c)} = \frac{p - ax_i}{2a} + \frac{caX_i - v_i}{2a(b + c)},$$

(22) if the right-hand side is in $[0, X_i]$. The second-order condition trivially holds. By summing over the $x_i$'s as given by (22) and combining that sum with (1), we get (5) and (6), and by inserting (6) into (22), we note that D's objective is to maximize $\sum_i x_i$, as given by (22) and combining that sum with (1), we get (5) and (6), and by Inserting (6) into (22), we get (4). Q.E.D.

Proof of Proposition 2. 
(i) From (3) we immediately get (when $j \neq i$ and using the Envelope theorem):

$$\frac{\partial u_i}{\partial x_j} = \frac{\partial u_i}{\partial p} \frac{\partial p}{\partial x_j} = -a [(b + c) x_i - eX_i] = -\frac{(b + c) p - acX - v_i n + \sum_{j \neq i} v_j}{n + 1},$$

when we substitute in for (4). With (7), we can write $\partial u_i / \partial x_j = -e_i / (n + 1)$.

(ii) When we combine (7) with (4) and (6), we get:

$$x_i = \frac{e_i}{a(b + c)(n + 1)} + \frac{cX_i}{b + c}$$

and

$$p = \frac{e_i}{(b + c)(n + 1)} + \frac{v_i}{b + c}.$$

Thus, we can write (3) as:

$$u_i \equiv x_i ((b + c) p - v_i) - pcX_i$$

$$= \left( \frac{e_i}{a(b + c)(n + 1)} + \frac{cX_i}{b + c} \right) \frac{e_i}{n + 1} - \left( \frac{e_i}{(b + c)(n + 1)} + \frac{v_i}{b + c} \right) eX_i,$$

which can be written as (8). Given (7), differentiating (8) gives Corollary 2. Q.E.D.

Proof of Proposition 3. In the text.

Proof of Proposition 4. 
(i) Since $u_D(x) + \sum_{i \in N} u_i(x) = bp(x) - cp(x) = vx - dx$, the o.c. when maximizing w.r.t. $x$ can be written as (15). The second-order condition trivially holds.

(ii) With (13), we can write (11) as

$$x = \frac{ac}{a(b + c)} X + \frac{ne - \sum_i t_i}{a(b + c)(n + 1)},$$

(24) This $x$ equals $x_{FB}$ if and only if (16) holds. Q.E.D.

Proof of Proposition 5. 
For a given $t_C$, D prefers to reduce $\pi_C$ as much as possible, so (IC$_C$) will bind. Solving (IC$_C$) for ($\pi_C - x$)$_C$ and inserting that term into (17), we note that D's objective is to maximize $-dx_C(t_C) + u_C(x_C(t_C)) - \alpha_c(x_C(t_C)) = u_D(x_C(t_C)) + u_C^0(x_C(t_C)) - u_C^0(\tilde{x}_C)$. D is thus maximizing the sum of payoffs (since $-u_C^0(\tilde{x}_C)$ is independent of $t_C$), implying the same outcome as in the first best: $x_C = x_{FB}$ and $t_C = d$.

To derive $\pi_C$, note that we can rewrite a binding (IC$_C$) to:

$$t_C \pi_C = u_C^0(\pi_C) - u_C^0(x_C(t_C)) - t_C x_C,$$

(25)
where both $u^0_C (\hat{x}_C)$ and the bracket follow from (8), and with (7) and (13), $e_i$ is replaced by $e$ when C ignores the contract while otherwise $e_i = e - t_C$. Thus, we can write (25) as:

$$t_C \pi_C = \frac{1}{a (b + c)} \left[ \frac{e^2}{4} - cavX - \frac{(e - t_C)^2}{4} + ca (v + t_C) X \right],$$

which can be rewritten as (18) when $t_C = d$. Q.E.D.

**Proof of Proposition 6.**

The proof starts by deriving $\max_{\bar{x}_i} u^0_i (\bar{x}_i, x_{-i} (t))$. From (23) and (4), we find $i$’s optimal response to $x_{-i} (t)$, if $i$ decided to ignore the contract:

$$x_i^f = \overline{p} - ax_{-i} (t) + \frac{caX_i - v}{2a} = x_i + \frac{t_i}{2a (b + c)},$$

where $x_i$ is given by (14). This results in a price

$$p^f = p - \frac{t_i}{2 (b + c)},$$

where $p = \overline{p} - a \sum_i x_i (t)$. Thus,

$$u^0_i (\bar{x}_i, x_{-i} (t)) = \left[ (b + c) p^f - v \right] x_i^f - p^f cX_i$$

$$= \left[ (b + c) \left( p - \frac{t_i}{2 (b + c)} \right) - v \right] \left( x_i + \frac{t_i}{2a (b + c)} \right) - \left( p - \frac{t_i}{2 (b + c)} \right) cX_i$$

$$= u^0_i (x (t)) + \left[ (b + c) \left( p - \frac{t_i}{2 (b + c)} \right) - v \right] \frac{t_i}{2a (b + c)} + \frac{cX_i t_i}{2 (b + c)}$$

$$= u^0_i (x (t)) + \frac{t_i^2}{4a (b + c)},$$

when we use (22). With this, (IC$_i$) boils down to

$$\tau_i \geq u^0_i (\hat{x}_i, x_{-i} (t)) - u^0_i (x (t)) = \frac{t_i^2}{4a (b + c)}.$$ (27)

D maximizes

$$u_D + \sum_{i \in M} \left[ u^0_i (x (t)) - u^0_i (\hat{x}_i, x_{-i} (t)) \right]$$

$$= -d \left[ \frac{ac}{a (b + c)} X + \frac{ne - \sum_{i \in M} t_i}{a (b + c) (n + 1)} \right] - \sum_{i \in M} \frac{t_i^2}{4a (b + c)}.$$

For each $t_i$, $i \in M$, the first-order condition becomes

$$\frac{d}{a (b + c) (n + 1)} - \frac{t_i}{2a (b + c)} = 0.$$

giving $t_i$. The second-order condition trivially holds.
To find \( \pi_i \), rewrite a binding (27) to:

\[
\tau_i = t_i(\pi_i - x_i) = \frac{t_i^2}{4a(b+c)} \Leftrightarrow \\
\pi_i = \frac{t_i}{4a(b+c)} + x_i(0) - \frac{t_i n - \sum_{j \neq i} t_j}{a(b+c)(n+1)} = x_i(0) + \frac{4m - 3(n+1)}{4a(b+c)(n+1)} t_i
\]

Thus, with decentralization, since we allow for a regime change that changes \( q \) to \( q' \) and \( m \) to \( m' \), even though the text above does not consider changes in \( q \). When inserting (20) into (11), we get:

\[
x = \frac{c}{b+c} X + \frac{e}{a(b+c)} - \frac{e + 2dm/(n+1)}{a(b+c)(n+1)}.
\]

Thus, with decentralization, \( x \) increases if:

\[
0 > \frac{e(n' - n)}{(n+1)(n'+1)} - 2d \frac{m'(n+1)^2 - m(n'+1)^2}{(n+1)^2(n'+1)^2} \Leftrightarrow \\
y < 2 \frac{m'(n+1)^2 - m(n'+1)^2}{(n+1)(n'+1)(n'-n)} = \frac{2}{(n'-n)} \left[ m' \left( 1 - \frac{n' - n}{n'+1} \right) - m \left( 1 + \frac{n' - n}{n+1} \right) \right]
\]

\[
= 2 \left[ \frac{m' - m}{n'-n} - \frac{m'}{n'+1} - \frac{m}{n+1} \right] = 2 \left[ 1 - \frac{q - q'}{n'+1} - \frac{m' - m}{n+1} \right].
\]

Setting \( q = q' \) and \( \Delta = m' - m = n' - n \) completes the proof. Q.E.D.

**Proof of Proposition 7.**

From now on we frequently use \( y \equiv e/d \). The following proof is more general than needed, since we allow for a regime change that changes \( q \equiv n - m \) as well as \( m \) (to \( q' \) and \( m' \)), even though the text above does not consider changes in \( q \). When inserting (20) into (11), we get:

\[
x = \frac{c}{b+c} X + \frac{e}{a(b+c)} - \frac{e + 2dm/(n+1)}{a(b+c)(n+1)}.
\]

Thus, with decentralization, \( x \) increases if:

\[
0 > \frac{e(n' - n)}{(n+1)(n'+1)} - 2d \frac{m'(n+1)^2 - m(n'+1)^2}{(n+1)^2(n'+1)^2} \Leftrightarrow \\
y < 2 \frac{m'(n+1)^2 - m(n'+1)^2}{(n+1)(n'+1)(n'-n)} = \frac{2}{(n'-n)} \left[ m' \left( 1 - \frac{n' - n}{n'+1} \right) - m \left( 1 + \frac{n' - n}{n+1} \right) \right]
\]

\[
= 2 \left[ \frac{m' - m}{n'-n} - \frac{m'}{n'+1} - \frac{m}{n+1} \right] = 2 \left[ 1 - \frac{q - q'}{n'+1} - \frac{m' - m}{n+1} \right].
\]

Setting \( q = q' \) and \( \Delta = m' - m = n' - n \) completes the proof. Q.E.D.

**Proof of Proposition 8.**

With (24) and (27) we can write D’s payoff as a function of \( m \):

\[
-dx - \sum_{i \in M} \frac{t_i^2}{4a(b+c)} = -d \left( \frac{ac}{a(b+c)} X + \frac{ne - m \left( \frac{2}{n+1} \right)}{a(b+c)(n+1)} - \frac{m \left( \frac{2}{n+1} \right)^2}{4a(b+c)} \right)
\]

\[
= \frac{d^2}{a(b+c)(m+q+1)^2} - \frac{dcX}{b+c} - \frac{de}{a(b+c)m+q+1}.
\]

By comparison, \( m' > m \) increases D’s payoff if

\[
\frac{m'}{(m'+q+1)^2} - \frac{m'}{m'+q+1} > \frac{m}{(m+q+1)^2} - \frac{m}{m+q+1} \Leftrightarrow \\
y < 1 - \frac{m'}{(m'+q+1)} - \frac{m}{(m+q+1)}. Q.E.D.
\]

**Proof of Proposition 9.**

We first derive the equilibrium payoff for a single district. From (26), (8), and (14), we have:
\[ u_i^0(\tilde{x}_i, x_{-i}(t)) = u_i^0(x(t)) + \frac{t_i^2}{4a(b+c)} \]
\[ = [u_i^0(x(t)) - x_i t_i] + x_i t_i + \frac{t_i^2}{4a(b+c)} \]
\[ = \frac{1}{a(b+c)} \left[ \left( c - nt_i + \sum_{j \neq i} t_j \right) - c(1 \leq i \leq n+1) \right] x_i + x_i t_i + \frac{t_i^2}{4a(b+c)}. \]

With (20), \( u_i^0(\tilde{x}_i, x_{-i}(t)) \) becomes
\[ \frac{1}{a(b+c)} \left[ \left( \frac{2}{n+1} \right) \left( \frac{(e + d)(n + l) - 2d(q + 1)}{(n + l)^2} \right) - cax_i \right] = \left( \frac{2}{n+1} \right) \left( \frac{(e + d)(n + l) - 2d(q + 1)}{(n + l)^2} \right) - cax_i. \]

Consider now a set \( L \) of \( l = |L| \) districts, taking as given \( n - l \). The sum of \( L \)'s payoffs is:
\[ \sum_{i \in L} \frac{1}{a(b+c)} \left[ \left( \frac{2}{n+1} \right) \left( \frac{(e + d)(n + l) - 2d(q + 1)}{(n + l)^2} \right) - cax_i \right]. \]

If the set \( L \) decentralizes, the new number is larger, say \( l' = l + \Delta > l \). This reduces total welfare if:
\[ \frac{l}{a(b+c)} \left( \frac{(e + d)(n + l) - 2d(q + 1)}{(n + l)^2} \right)^2 > \frac{l'}{a(b+c)} \left( \frac{(e + d)(n + l) - 2d(q + 1)}{(n + l')^2} \right)^2 = \Omega^2. \]

The r.h.s. of (28), \( \Omega^2 \), is, as a function of \( y = e/d \), drawn in the figure. When \( y \in (-\infty, 1 - \frac{2m'}{n+1}) \), \( \Omega > 0 \) and \( \Omega^2 \) decreases from 1 to 0. When \( y \in (1 - \frac{2m'}{n+1}, 1 - \frac{2m}{n+1}) \), \( \Omega < 0 \) and \( \Omega^2 \) increases from 0 to \( \infty \). When \( y > 1 - \frac{2m'}{n+1} \), \( \Omega > 0 \) and \( \Omega^2 \) decreases from \( \infty \) to 1 when \( y \) increases toward \( \infty \).

Thus, when \( y \in (1 - \frac{2m'}{n+1}, 1 - \frac{2m}{n+1}) \) and \( \Omega < 0 \), the inequality (28) can be written as:
\[ y < \frac{\sqrt{l'} \left( \frac{n' + 1}{n + 1} \right) - \frac{2m'}{n+1} - \frac{2m}{n+1}}{1 - y - \frac{2m'}{n+1} - 1} \Rightarrow \]
which clearly satisfies \( y \in (1 - \frac{2m'}{n'+1}, 1 - \frac{2m}{n+1}) \).

If instead \( \Omega > 0 \), (28) implies:

\[
\frac{l}{\sqrt{\nu}} \left( \frac{n' + 1}{n + 1} \right) > 1 + \frac{2m'}{n'+1} - \frac{2m}{n+1} - 1.
\] (29)

If, moreover, the denominators are positive, then (29) implies:

\[
y > \bar{c}_L \equiv 1 - \frac{2m}{n + 1} + \frac{2m'}{n'+1} - \frac{2m}{n+1} \sqrt{\nu} \left( \frac{n'+1}{n+1} \right) - 1.
\]

If instead the denominator on the r.h.s. of (29) is negative, so that \( y < 1 - \frac{2m'}{n'+1} \), then (29) implies:

\[
y < \bar{c}_L \equiv 1 - \frac{2m}{n + 1} + \frac{2m'}{n'+1} - \frac{2m}{n+1} \sqrt{\nu} \left( \frac{n'+1}{n+1} \right) - 1.
\]

Note also that \( \Omega < -1 \) (which implies \( \Omega^2 > 1 \)) if:

\[
y \leq 1 - \frac{m}{n + 1} + \frac{m'}{n' + 1}.
\]

Finally, note the following:

**Lemma:** The l.h.s. of (28) is larger than 1 if and only if \( L \) is large:

\[
\frac{l}{\nu} \left( \frac{n' + 1}{n + 1} \right)^2 > 1 \iff \frac{l'}{1 + n'} + \frac{l}{n + 1} > 1.
\]

**Proof:** Note that

\[
\frac{l'}{\nu} \left( \frac{n' + 1}{n + 1} \right)^2 > 1 \iff \frac{l' - v}{\nu} \left( \frac{n'}{n' + 1} \right)^2 - 2v \left( \frac{n'}{n' + 1} + v \right) > 1 \iff \frac{l'}{1 + n'} > \frac{n' + 1}{2 (n' + 1) - v}.
\] (31)
In addition, (30) is equivalent to
\[
\frac{2(n+1)v + v^2}{(n+1)^2} > \frac{v}{l} \Leftrightarrow \\
\frac{l}{n+1} > \frac{n+1}{2(n+1)+v}.
\] (32)

Since (31) and (32) are equivalent, we can also sum them and write:
\[
\frac{l'}{1+n'} + \frac{l}{n+1} > \frac{n'+1}{2(n'+1)-v} + \frac{n+1}{2(n+1)+v} = \frac{n'+1}{n+n'+2} + \frac{n+1}{n+n'+2} = 1.
Q.E.D.

Proof of Proposition 10.
(i) If the presence of D leads to centralization and \(n' > n\), then \(x\) increases if:
\[
\frac{e}{a(b+c)(n+1)} > \frac{e+2dm'/(n'+1)}{a(b+c)(n'+1)} \Leftrightarrow \\
y > \frac{2m'(n'+1-v)}{(n'+1)v} = \frac{2m'(n+1)}{(n'+1)v} = 2\left(1 + \frac{m}{v}\right) \left(1 - \frac{v}{n'+1}\right)
\]
\[
= \frac{2(m+v)(n+1)}{(n+v+1)v}.
\]
(ii) If the presence of D leads to centralization and thus \(n' < n\), then \(x\) increases if
\[
\frac{e}{a(b+c)(n+1)} > \frac{e+2dm'/(n'+1)}{a(b+c)(n'+1)} \Leftrightarrow \\
y < \frac{-2m'(n+1)}{(n'+1)v}, \quad Q.E.D.
9 Appendix B: Participation Constraints and General Contracts

[As explained in Remark 4, this appendix adds to our results on conservation contracts by discussing participation constraints and more general contracts. We are happy to skip this material to keep the paper short, or to include it to strengthen our section on contracts.]

Consider the setting where D offers linear contracts to \( m \) districts (Section 5.3). There can be multiple equilibria at the extraction stage: If the other districts expect \( i \) to extract more, such that \( x_i > \pi_i \), then the other districts find it optimal to extract less. This strengthens \( i \)'s incentive to extract and \( x_i > x_i \) becomes strictly preferred by \( i \). In this case, \( i \) receives no transfers and the outcome is \( x(\mathbf{t}_i) \), where \( \mathbf{t}_i = (t_1, \ldots, t_{i-1}, 0, t_{i+1}, \ldots, t_m) \). Of all the multiple equilibria, D prefers the equilibrium in which extraction levels are \( x(\mathbf{t}) \). But district \( i \in M \) prefers \( x(\mathbf{t}_i) \) to \( x(\mathbf{t}, \pi_i) \) only if:

\[
0 < u_0^i(x(\mathbf{t})) + t_i \cdot (\pi_i - x_i) - u_0^i(x(\mathbf{t}_i)).
\]

(PC\(_i\))

If (PC\(_i\)) is violated, then \( i \) would prefer to reject the contract immediately, by announcing to the other districts that it will not accept any transfers from D. If such a promise is credible, then D must take the participation constraints (PC\(_i\)) into account. The problem for D is then to select the \( m \) pairs \((t_i, \pi_i)\) in order to maximize \( u_D - \sum_{i \in M} t_i \cdot (\pi_i - x_i) \) subject to the \( m \) incentive constraints and the \( m \) participation constraints.

**Proposition 11.** Suppose D contracts with \( m \leq n \) districts.

(i) When only the \((IC_i)\)'s binds, the optimal contract for D is as in Proposition 6.

(ii) When only the \((PC_i)\)'s binds, the optimal contract for D is:

\[
\begin{align*}
t_{PC} &= \frac{(n+1)d - (n-1)e}{2 + 2m(n-1)}, \\
\pi^{PC}_i &= x_i(0) + \frac{1}{a(b+c)} \left[ \frac{n-1}{(n+1)^2} e + \frac{2n(m-1) - n^2}{(n+1)^2} t \right].
\end{align*}
\]

(iii) Every \((IC_i)\) is strictly stronger than \((PC_i)\) if and only if districts are weak:

\[
e < -\left( \frac{4m-n-3}{4} \right) t.
\]

To understand part (iii), note that when \( e \) and \( t \) are large, then district \( i \) benefits when the other districts conserve. It is then tempting for \( i \) to reject D’s offer publicly (rather than simply ignoring it), which implies that (PC) is harder to satisfy than is (IC). Note that a district’s size is irrelevant for whether (IC) or (PC) is strongest, as well as for the equilibrium contract, described by (i)-(ii).

An attractive outside option to \( i \) means that D must increase the baseline \( \pi_i \) to ensure that the deal is sufficiently beneficial to \( i \). This is costly to D, but when (PC) binds, D can reduce this cost by reducing \( t \). Consequently, the larger \( e \) is, the smaller is the equilibrium \( t \) when (PC) binds, as illustrated in part (ii) of the proposition. This argument fails when the binding constraint is instead (IC): At the extraction stage, \( i \) can still ignore the offer from D but that will not influence other districts’ extraction levels. Such a deviation would thus not be especially beneficial when \( e \) is large, so the equilibrium \( t \) does not depend on \( e \) when (IC) binds.

**Corollary 11.** At the equilibrium contracts, the conservation level is too large compared to
Figure 3: In our two-district example, there is too little conservation if and only if $e/d > 9/19$.

the first best if and only if districts are weak ($e/d$ is small):

$$x < x_{FB} \iff t > t_{FB} \iff e/d < \epsilon,$$

where

$$\epsilon \equiv \begin{cases} \frac{(n+1)^2-4m}{(n+1)(1+m(n-2))} & \text{if only (IC) binds}; \\ \frac{(n-1)(1+m)}{4m(n+1)-(n-1)(n+3)} & \text{if only (PC) binds}; \\ \frac{(n+1)^2-4m}{(n+1)(1+m(n-2))} \frac{(n-1)(1+m)}{4m(n+1)-(n-1)(n+3)} & \text{if both (IC) and (PC) bind}. \end{cases}$$

Example. To illustrate the results with some numbers, consider the situation with two districts, A and B, so $m = n = 2$. In this case, $t_{IC} = 2d/3$ and (PC) does not bind when $e/d < -1/2$. Likewise, $t_{PC} = d/2 - e/6$ and (IC) does not bind for this $t$ when $e/d > -3/7$. When $e/d \in [-1/2, -3/7]$, (IC) and (PC) both bind and $t$ is then given by (33), so $t = -4e/3$. This is all illustrated in Figure 3. In this example, the first best (16) requires that $t_{FB} = 3d/4 + e/4$. In Figure 3, $t_{FB}$ crosses the equilibrium $t$ when $e/d = -9/19$, and $t_{FB}$ crosses $t_{IC}$ when $e/d = -1/3$. Thus, when both (IC) and (PC) must be satisfied, there is too little conservation if $e/d > -9/19$. If only (IC) had to be satisfied, the condition would be $e/d > -1/3$.

So far, we have restricted attention to linear and bilateral contracts since real-world conservation contracts do take this form. However, such contracts may or may not be optimal from D’s point of view. Suppose instead that D could offer transfers that were contingent on the vector of extraction levels, $\tau_i(x)$. It turns out that while D must still ensure that the incentive constraints are satisfied, every participation constraint can be relaxed. In fact, (PC) can be relaxed in a simple way by offering payments if and only if $x_i = x_i(t_{IC})$, and zero payment for every other $x_i \neq x_i(t_{IC})$.

**Proposition 12.** Suppose D can offer any contract $\tau_i(x) \geq 0$ to $i \in M$.

(i) The incentive constraints are $(IC_i)$ as before.

(ii) The participation constraints $(PC_i)$ can be relaxed so that they are always weaker than the incentive constraints.
(iii) Consequently, the optimal contract implements $x_i$'s and transfers which are identical to those of 6.

Thus, when (IC) is in any case the binding constraint, then D cannot do any better than sticking to the linear contracts. This is the case when districts are weak and extraction protection-driven. If, however, districts are strong and extraction sales-driven, then (PC) is the binding constraint and D can do better with nonlinear contracts.

**Corollary 12.** From D's perspective, nonlinear contracts are inefficient if and only if (PC) binds at $t = t_{IC}$:

$$\frac{e}{d} > -\frac{4m - n - 3}{2(n + 1)}.$$  

Condition (PC) can be relaxed in a simple way by offering payments if and only if $x_i = x_i(t_{IC})$, and zero payment for every $x_i \neq x_i(t_{IC})$. If the districts cannot credibly commit to decline transfers from D, then (PC) would not be binding in the first place. In either case, since (PC)'s can easily be relaxed, Section 6 focuses on the case where only (IC)'s bind.

**Proof of Proposition 11.** Part (i) coincides with Proposition 6.

(ii) Note that $(PC_i)$ can be rewritten as:

$$t_i\bar{x}_i \geq u^0_i(x(t_\cdot \cdot)) - [u^0_i(x(t)) - t_ix_i]$$

where both $u^0_i(x(t_\cdot \cdot))$ and the bracket follow from (8), so:

$$t_i\bar{x}_i \geq \frac{1}{a(b+c)} \left[ \left( \frac{e + \sum_{j \neq i} t_j}{n + 1} \right)^2 - cavX_i \right] - \frac{1}{a(b+c)} \left[ \left( \frac{e - nt_i + \sum_{j \neq i} t_j}{n + 1} \right)^2 - ca(v+t_i)X_i \right] = \frac{t_i}{a(b+c)} \left[ \frac{2n \left( e + \sum_{j \neq i} t_j \right) - n^2t_i}{(n + 1)^2} + caX_i \right].$$ (34)

Thus, D's problem becomes to maximize:

$$u_D + \sum_{i \in M} \left[ u^0_i(x(t)) - u^0_i(x(t_\cdot \cdot)) \right] = -dx + \sum_{i \in M} [x_it_i - t_i\bar{x}_i]$$

$$= -dx + \sum_{i \in M} x_it_i - \sum_{i \in M} t_i \cdot \frac{2n \left( e + \sum_{j \neq i} t_j \right) - n^2t_i}{(n + 1)^2} + caX_i.$$  

Since $x_i$ is given by (14) and $x$ by (24), the f.o.c. w.r.t. $t_i$ becomes:

$$0 = \frac{d}{a(b+c)(n + 1)} + \frac{(b+c)\overline{p} + ac(n + 1)X_i - acX - v - 2t_in + \sum_{j \neq i} t_j}{a(b+c)(n + 1)}$$

$$+ \frac{1}{a(b+c)(n + 1)} \sum_{j \in M \setminus i} t_j - \frac{1}{a(b+c)} \left[ \frac{2n \left( e + \sum_{j \neq i} t_j \right) - n^2t_i}{(n + 1)^2} + caX_i \right]$$

$$- \sum_{j \in M \setminus i} \frac{t_j}{a(b+c)(n + 1)^2}.$$  

\footnote{From Proposition 11 it follows that if $t$ is set according to (20), then (PC) is not binding if (33) holds for that $t$. This gives Corollary 12.}
Note that $X_i$ disappears from the f.o.c., so we get the same $t_i = t_{PC}$ for every $i \in M$. The f.o.c. thus simplifies to:

$$
0 = (n + 1) d + (n + 1) e - t_{PC} (2n - m + 1) (n + 1) + (m - 1) (n + 1) t_{PC} - [2n - 2n (n - m + 1) t_{PC}] - 2n (m - 1) t_{PC} = (n + 1) d - (n - 1) e - 2 [(n - m + 1) + n (m - 1)] t_{PC},
$$

which reveals that the second-order condition clearly holds. By solving for $t$, we get:

$$
t_{PC} = \frac{(n + 1) d - (n - 1) e}{2 [(n - m + 1) + n (m - 1)]} = \frac{(n + 1) d - (n - 1) e}{2 + 2m(n - 1)}.
$$

We can find $\pi_i$ by inserting $t_{PC}$ and $x_{i,0}$ from (14) into (34):

$$
\pi_i^{PC} = x_i (0) + \frac{1}{a (b + c)} \left[ \frac{n - 1}{(n + 1)^2} e + \frac{2n (m - 1) - n^2}{(n + 1)^2} t \right].
$$

(iii) Note that (IC) is harder to satisfy than (PC) if $\pi_i^{IC} > \pi_i^{PC}$. A simple comparison gives (33). \textit{Q.E.D.}

\textbf{Proof of Proposition 12.} (i) It is easy to see that (IC$_i$) remains unchanged if D can use more general contracts: If D wants to implement a particular vector $x$, it must offer each $i \in M$ a transfer $\tau_i (x)$ that makes $i$ weakly better off compared to selecting any other $x_i$ (leading to a different transfer). To discourage such deviations, D should ensure that $i$ receives no transfer if $i$ deviates from the implemented plan. Thus, the incentive constraint is

$$
u_i^0 (x (\tau)) + \tau_i (x (\tau)) \geq u_i^0 (\tilde{x}_i, x_{-i} (\tau)) \forall \tilde{x}_i > \pi_i,
$$

just as before.

(ii) Next, note that the participation constraint can always be weakened to make it weaker than the incentive constraint. To see this, write the participation constraint as:

$$
u_i^0 (x (\tau)) + \tau_i (x (\tau)) \geq u_i^0 (x (\tau_{-i})),
$$

and note that it is always possible to select $\tau (x)$ in such a way that $x_{-i} (\tau_{-i}) = x_{-i} (\tau)$, that is, such that no $j \neq i$ will change $x_j$ if $i$ announces that $i$ will not accept transfers from D. This is achieved, for example, if $j$ receives transfers only when $x_j = x_j (\tau)$. Of course, it may be that the transfer $\tau_j$ must be larger when $i$ rejects the contract and thus selects $x_i \neq x_i (\tau)$, but this larger transfer will not have to be paid by D in equilibrium.

(iii) Thus, only the incentive constraint will bind when $\tau (x)$ can be a general function. Inserting the binding incentive constraints into D’s objective function gives, as before, that D selects $\tau$ or, equivalently, $x$, to maximize:

$$
u_D + \sum_{i \in M} u_i^0 (x) - u_i^0 (\tilde{x}_i (x_{-i}), x_{-i}),
$$

where $\tilde{x}_i (x_{-i}) = \arg \max_{x_i} u_i^0 (x_i, x_{-i})$. This is the same problem as in the proof of Proposition 6, and the outcome for $x_i$ and $\tau$ are thus also identical. \textit{Q.E.D.}