Conservation Contracts for Exhaustible Resources

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Conservation: Tropical Forests

- Only in 2000-2012, tropical rainforest in South America was reduced by 4.2%, in Asia by 12.5%, and in Africa by 2.8%.
- Deforestation in the tropics has contributed to 30% of man-made CO_2 emissions, and it contributes to 10-20% of annual greenhouse gas emissions.
- Negative externalities $2-4.5 trillion a year (the Economist, 2010)
- Deforestation could be halved at a cost of $21–35 billion per year.

Conservation Contracts

- **Contracts Exists:** The United Nations, the World Bank, and the Norwegian government are offering financial incentives to countries successful in reducing deforestation.
- Contracts are signed with an increasing number of countries: Brazil, Indonesia, Guyana, Ethiopia, Vietnam, Mexico, Tanzania, Congo.
- **Simple contracts**: Rates are harmonized and constant: 5 USD/ton avoided CO2, for every unit of deforestation less than some (negotiated) benchmark
- **Limited success** so far / Too early to judge

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- First (?) paper on how to contract on slowing resource depletion. (well...not yet a paper...but in progress)

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  - **Today:** dynamic model of contracting in the presence of externalities

Outline

- A Model of Extraction
- The First Best
- The Equilibrium
- Generalizations
- Policies
- Conclusions

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- Common discount factor $\delta \in [0, 1]$

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- Reasonable if:

$$y_i^t < \tilde{y} \equiv (1-\delta)\, b/2a.$$

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- Can order according to size, $y_1^0 \geq y_2^0 \geq ... \geq y_n^0$.

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- With a large number of small stocks ($y_j \to 0$), the steady-state conservation level is

$$y^T = \max\left\{0, \frac{e-b}{a}\right\}.$$

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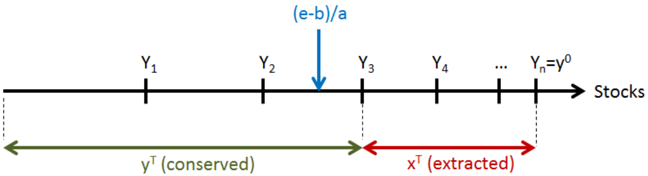

Figure: *The largest stocks are conserved, while the smallest stocks are depleted.*

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- *For any two consecutive periods, we have:*

$$\left[b - e - a\left(2 - w\right)x^{t}\right] + a\sum_{i=1}^{i-1} y_i^0 = \delta\left[b - e - a\left(2 - w\right)x^{t+1}\right]$$

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- Otherwise, the speed of extraction is too high.

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3. *The equilibrium speed is given by:*

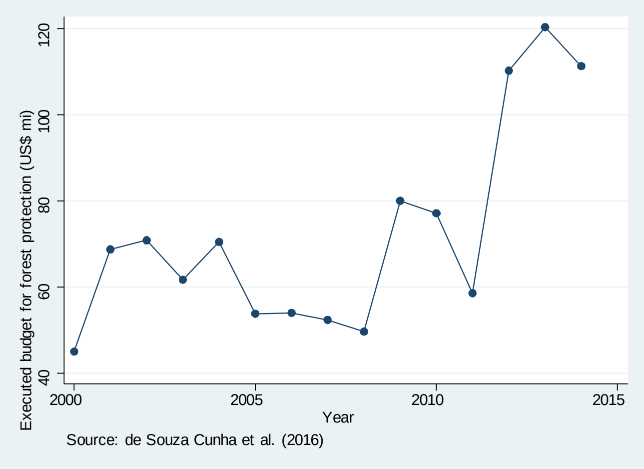
$$b - e_i - c_i - a\,(2-w)\,x^t + a\sum^{i-1} y_j^t = \delta\left[b - e_i - c_i - a\,(2-w)\,x^{t+1}\right]$$

Extensions

Illegal Deforestation

Country\Year	Forest Cover 2000 (1000 ha)	Deforestation 2000-2010	Illegal logging in 2013
Brazil	545943	5%	$>$ 50%
Cameroon	22116	10%	65%
Ghana	6094	19%	70%
Indonesia	99409	5%	60%
Laos	16433	6%	80%
Malaysia	21591	5%	35%
Papua New Guinea	30133	5%	70%
Rep. Congo	22556	1%	70%

Enforcement Expenditures



Extension I: Protection Costs

- If $y_i^t - x_i^t$ is conserved, the profit from illegal logging is p^t at each unit of the forest.
- Expected penalty must be at least as large as the profit
- The cost of monitoring is thus $\alpha p^t \left(y_i^t - x_i^t\right)$ for some $\alpha \geq 0$. So,

$$u_i^t = \beta p^t x_i^t - \alpha p^t \left(y_i^t - x_i^t\right) - c_i x_i^t + s_i^t,$$

- This is the model of Harstad and Mideksa (*ReStud*, '17)
- (That paper also studies contracting with a subset of agents, and endogenizes institutions/(de)centralization. But the model is static..)
- All results above continue to hold, qualitatively.

Extension II: Outside Option

- Above we have assumed that the outside option is $x_i^t = y_i^t$
- Unreasonable unless each period long/δ is small
- In steady state, each i is a potential monopolist and would like to extract $f_i\left(y_i^t\right)$ if ignoring the contract.
- Suppose outside option is indeed some increasing $f\left(y_i^t\right) \in \left[0, y_i^t\right]$.
- Results above tend to hold, qualitatively.

Extension I and II Combined

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- *For larger* α*, the results are overturned.*

Robustness: The Crucial Assumptions

1. Extract from i first iff:

$$(c_j + e_j) - (c_i + e_i) > \frac{a}{1-\delta} \begin{bmatrix} \beta \left[H(y_i) - H(y_j) \right] \\ -(\alpha + \beta) \left[H(F(y_i)) - H(F(y_j)) \right] \end{bmatrix},$$

where $H(y_i) = z - \delta F_i(z)$. The r.h.s. is positive if $y_i > y_j$ iff

$$\frac{\alpha}{\beta} < \alpha_1 = \frac{H(y_i) - H(y_j)}{H(F(y_i)) - H(F(y_j))} - 1.$$

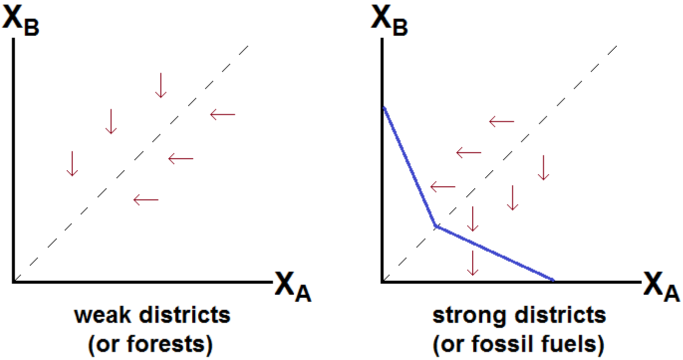
2. Too much is extracted from i iff:

$$\frac{\alpha}{\beta} < \alpha_2 = \frac{\sum_{j \neq i} y_j - F(y_j)}{\sum_{j \neq i} F(y_j)} = \frac{\sum_{j \neq i} y_j}{\sum_{j \neq i} F(y_j)} - 1 > 0$$

3. The speed is too large iff:

$$\frac{\alpha}{\beta} < \alpha_3 = \frac{1}{(1-\delta)} \left[\frac{\sum_{j \neq i} y_j^t}{\sum_{j \neq i} F_j\left(y_j^t\right)} - 1 \right]$$

Current Research: Dynamics



- If strong/coal: conserves everything in the largest district
- If weak/forests/illegal: conserves everything in the smallest district

Policy Implications

- It might indeed be efficient to offer contracts to the largest tropical forest owners, such as Brazil and Indonesia, according to this theory
- However, the optimal contracts are highly asymmetric
- Harmonized contracts achieve too little conservation at a too large cost.

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  2. Steady state conservation decreases

Policies and Comparative Static

- With m similar buyers with demand function $p^t = b - a_m x_m^t$, aggregate demand is $p^t = b - ax^t$ where $1/a = \sum_m 1/a_m$
- If some buyer(s) boycott, a increases
- A larger a increases the difference to the first best in all results
- Intuition: Steeper demand curve makes it easy/tempting for the contract-provider to reduce the price.
- Thus, a boycott has the following consequences for small α:
  1. Extraction may switch from cleanest/less expensive to smallest
  2. Steady state conservation decreases
  3. Speed of extraction increases

Long-Term Contracts (with Commitment)

With commitment, payments can be delayed
This relaxes incentive constraints in the meanwhile
...and then, there is no reason to raise x_i^t to lower s_j^t
Outcome becomes first-best (after the very first period)
If principal can ask for money up front, first-best also in first period.
Long-term contracts lead to slower extraction and more conservation.

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- Boycotts makes the equilibrium worse.

Robustness: Non-negative side payments

- Going back in time, x^t increases and p^t decreases
- This reduces the temptation to "extract it all" and waiting becomes more attractive
- It is possible that $s_j^t = 0$ is sufficient
- When $s_j^t = 0$, there is less need to raise x_i^t, since s_j^t cannot be reduced further.
- If $s_j^t = 0$ for many agents, conservation will take place in any case, and the principal may be better off waiting before entering the game
- This is the opposite of the "Green Paradox"
- Equilibrium may be in mixed strategies (Harstad '16).