Deforestation and REDD

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Outline

1. Deforestation: Drivers and solutions
2. Models of deforestation
3. Models of conservation (contracts)

Conservation: Tropical Forests

- 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.
- 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%.
- Negative externalities \$2-4.5 trillion a year (the Economist, 2010)
- Deforestation could be halved at a cost of \$21–35 billion per year.

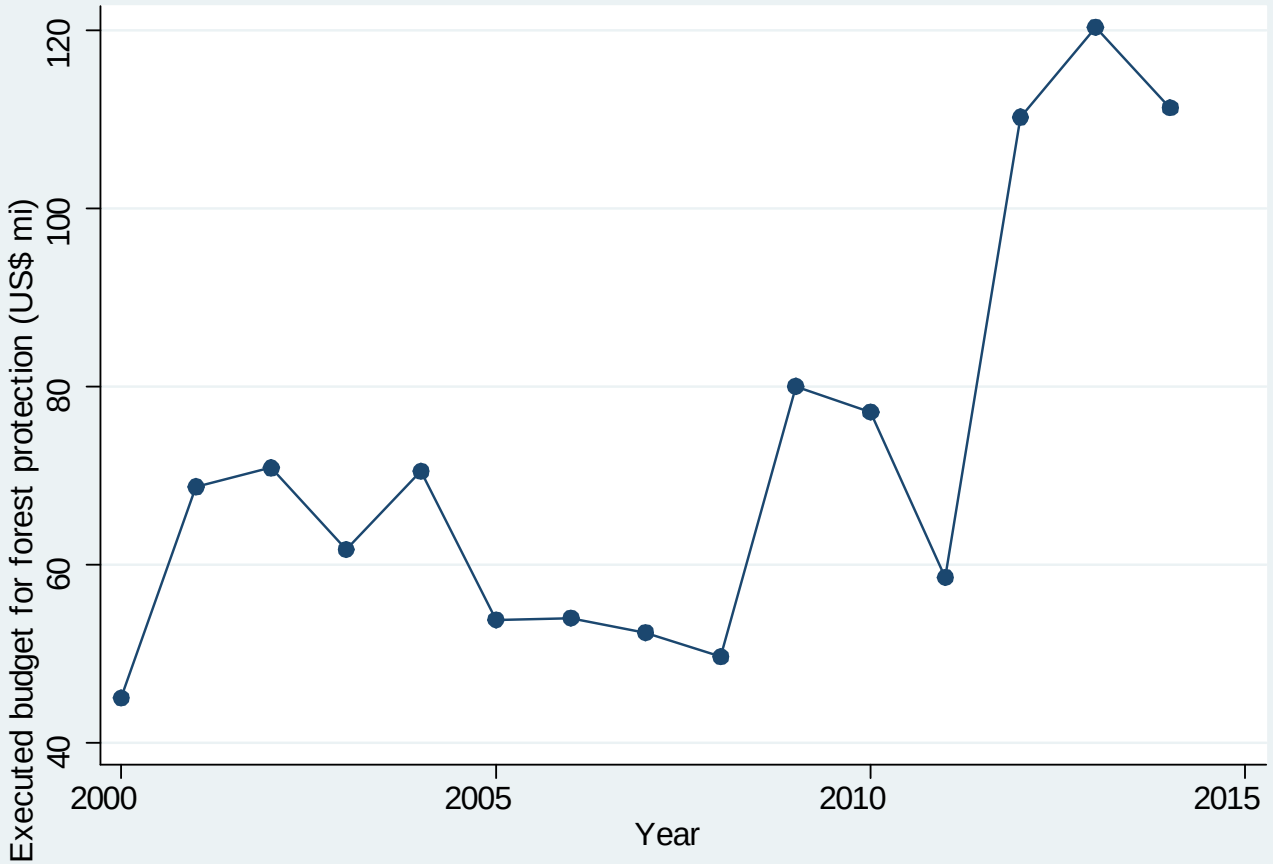
Deforestation: Causes

- Causes of deforestation: Profit, illegal logging, weak property rights, costly monitoring (Alston and Andersson, 2011; Angelsen, 2010; Damette and Delacote, 2012)
- "Deforestation in Indonesia is largely driven by the expansion of profitable and legally sanctioned oil palm and timber plantations and logging operations" (Burgess et al, 2013)
- Each percentage point of palm-driven poverty reduction corresponds to a 1.5–3 percentage point loss of forest area in Indonesia (Edwards '18).
- In Himalaya: "the Forest Department was poorly staffed and thus unable to implement and enforce the national policies" (Shyamsundar and Ghate, 2014)

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



Source: de Souza Cunha et al. (2016)

Deforestation: Solutions

- Before 2005: rapid deforestation in the Brazilian Amazon was a consequence of lax enforcement of laws prior to the mid-2000s.
- Then, with stronger legal fees, deforestation fell (Burgess, Costa, Olken '18)
- Deforestation observed from 2007 through 2011 was 75% smaller than it would have been in the absence of fines (Assuncao et al. '13)
- Payments for Ecosystem Services (PES) necessary to internalize externalities
- Uganda: Benefit is 2.4 times as large as the program costs (Jayachandran et al., '17)

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 a set of individual countries: Brazil, Indonesia, Guyana, Ethiopia, Vietnam, Mexico, Tanzania, Congo.
- **Simple contracts**: Rate is uniform and constant: 5 USD/ton avoided CO2, for every unit of deforestation less than some (negotiated) benchmark
- **No districts** (within countries) are offered such contracts
- **Limited success** so far / Too early to judge

Conservation Contracts: General Motivation

- Many environmental problems are linked to resource extraction
- Traditional environmental policy regulates (end-of-pipe) emisson
- Regulating supply can be a better alternative
- Even for a climate coalition, the possibly most efficient policy is to target the fossil fuel deposits in nonparticipating countries.
- **But what is the best conservation contract?**

Models of Conservation

- Let x_i be deforestation level in district $i \in N \equiv \{1, ..., n\}$.
- Demand is $p = \overline{p} - a \sum_i x_i$.

1. In a **sales-driven** model, profit is:

$$u_i = p x_i.$$

2. In an **illegal** logging model, enforcement is preventive at unit j if there is a large expected penality:

$$\theta_j \geq p.$$

   - With stock X_i, protection cost c, marginal opportunity value v_i:

$$u_i = -c \sum_{j \in i} \theta_j - \sum_{j \in i} \left(v_i \mid \theta_j < p \right) = -cp \left(X_i - x_i \right) - v_i x_i.$$

3. By **combining** the two models, we get:

$$u_i = bpx_i - cp \left(X_i - x_i \right) - v_i x_i.$$

Alternative Interpretations

Forests	Coal
Weak property rights	Strong property rights
c large	b large

- While c may be high for forests, c is small for fossil fuels
- All extraction could be illegal, and b could be the *probability* that i captures the cutter('s revenue) in the region that is not highly protected.
- Parameter b could be the government's *weight* on the utility/profit of the extractor (whether legal or illegal)

The Market Equilibrium

- District i cuts more if
  - large stock X_i or small value v_i,
  - price likely to be high, i.e. if neighbors are likely to cut less,
  - small stock X_j or large value v_j, $j \neq i$:

$$x_i = \frac{cX_i}{b+c} + \frac{(b+c)\,\overline{p} - acX - v_i\,(n+1) + nv}{a\,(b+c)\,(n+1)}.$$

- Total extraction increases if
  - large total stock $X \equiv \sum_i X_i$ or small $v \equiv \sum_i v_i / n$

$$\begin{aligned} x &= \frac{n}{n+1}\left(\frac{\overline{p}}{a} - \frac{v}{b+c}\right) + \frac{cX}{(b+c)\,(n+1)}, \\ p &= \frac{\overline{p}}{n+1} - \frac{acX - anv}{(b+c)\,(n+1)}, \end{aligned}$$

Externalities are Key

Proposition

- *If j conserves, i benefits IFF property rights are* **strong** *(large b/c):*

$$\frac{\partial u_i}{\partial\left(-x_j\right)}=\frac{e_i}{n+1}\equiv\frac{\left(b+c\right)\overline{p}-acX-v_i\left(n+1\right)+nv}{n+1}$$

- *Large districts conserve relatively more IFF $e>0$:*

$$\frac{x_i}{X_i}-\frac{x_j}{X_j}=\left(\frac{e_i}{X_i}-\frac{e_j}{X_j}\right)\frac{1}{a\left(b+c\right)}$$

- *Centralization leads to more conservation IFF $e_i>0$.*

(De)Centralization

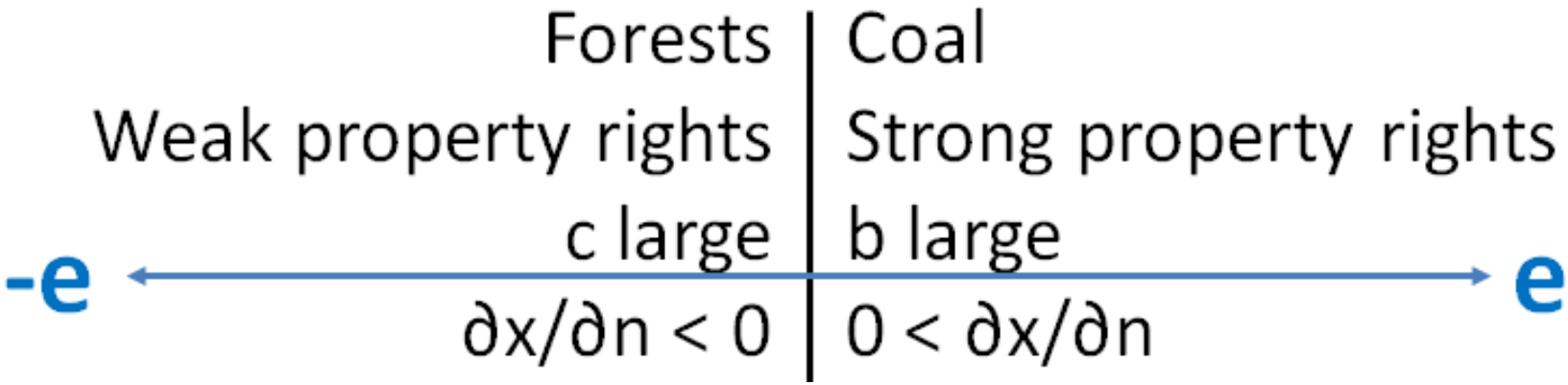
Corollary

- **Decentralization** *increases extraction IFF districts are* **strong** *:*

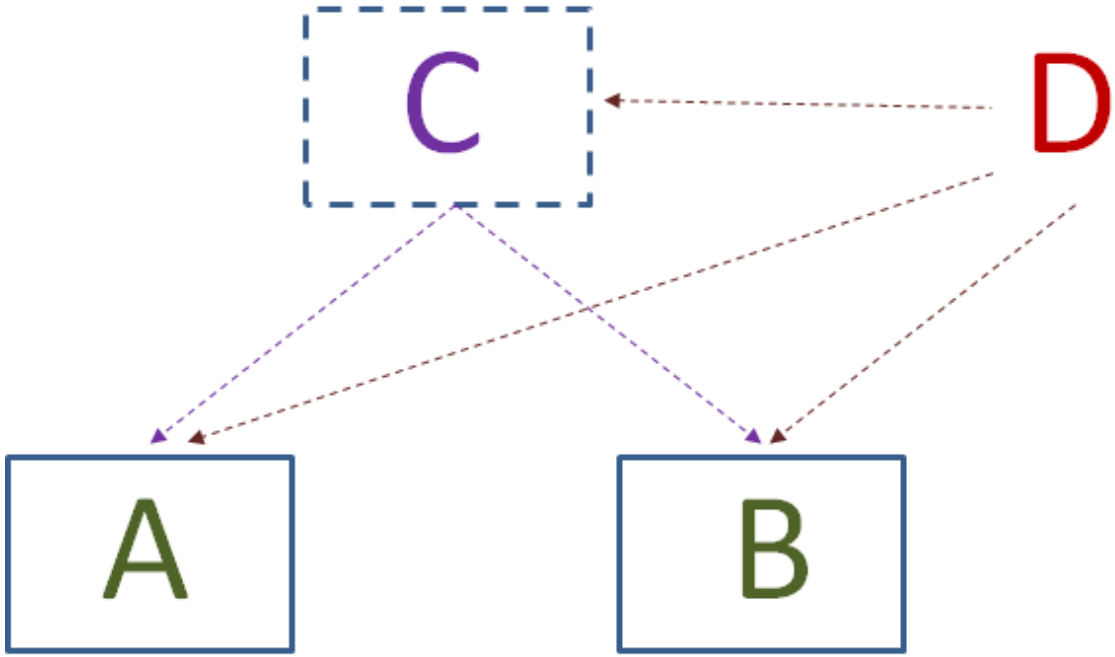
$$sign\frac{\partial x}{\partial n} = sign\ e\ ,\ where\ e \equiv \sum_i e_i / n$$

- **Decentralizing** power contributed to deforestation in Indonesia (Burgess et al, 2013)
- **The opposite** happened in Himalaya (Somanathan et al, 2008; Baland et al, 2010)

(De)Centralization: Takeaways



REDD+


C
D
A
B

Contracts under Centralization

- Consider a "donor" D who has payoff $u_D = -dx$ (minus transfers).
- Suppose D selects t_C and $\overline{x}_C$, and offers $t_C \cdot \max\{0, \overline{x}_C - x\}$ to C, in order to maximize

$$u_D = -dx - t_C \cdot \max\{0, \overline{x}_C - x\}.$$

- Since C's problem is nonconcave, we must ensure that $u_C(t_C) \geq u_C(0)$. This requires

$$u_C^0(x) + t_C \cdot (\overline{x}_C - x) \geq u_C^0(\widehat{x}) \; \forall \widehat{x} > \overline{x}_C. \qquad \text{(IC)}$$

- Given this constraint, the solution to D's problem is

$$t_C = d, \overline{x}_C = \frac{e + 2qX}{2a(b+c)} - \frac{d}{4a(b+c)}.$$

- This (Pigou) subsidy implements the **first best**.

Contracts under Decentralization

- Suppose D offers $t_i \cdot \max\{0, \overline{x}_i - x\}$ to $m \in \{1, ..., n\}$ independent districts.
- D's problem is to select the $\overline{x}_i$'s and $\mathbf{t} = (t_1, .., t_m)$ to maximize:

$$u_D = -dx(\mathbf{t}) - \sum_{i \in \{1,...,m\}} t_i \cdot \max\{0, \overline{x}_i - x_i(\mathbf{t})\}$$

- ...subject to the constraint that $x_i(\mathbf{t})$ is a best reply for every i:

$$u_i^0(\mathbf{x}(\mathbf{t})) + t_i \cdot (\overline{x}_i - x_i) \geq u_i^0(\widehat{x}_i, x_{-i}(\mathbf{t})) \, \forall \widehat{x}_i > \overline{x}_i. \qquad (IC_i)$$

- **Leakage:** Conservation in one district makes $n-1$ other districts want to extract more.

Contracts: Equilibrium

Proposition

- *The equilibrium contract is:*

$$t = \frac{2}{n+1} d \text{ and } \overline{x}_i = x_i(\mathbf{0}) - \frac{3(n+1) - 4m}{4a(b+c)(n+1)} t$$

- *Decentralization => more extraction IFF property rights strong:*

$$\frac{e}{d} > -2\left(\frac{m-l+1}{n-l+2} + \frac{m}{n+1} - 1\right)$$

- *D prefers centralization IFF property rights are strong:*

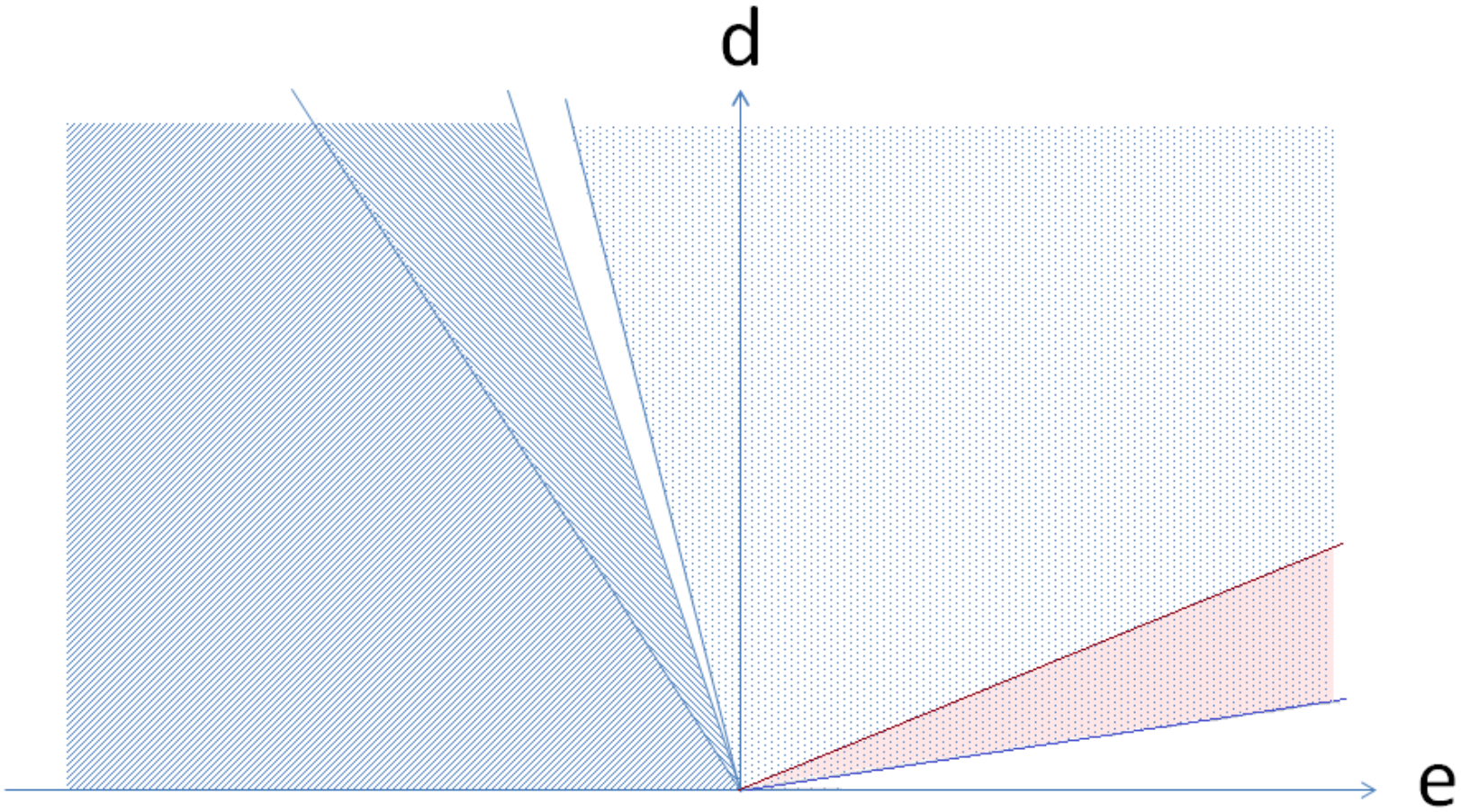
$$\frac{e}{d} > -\left(\frac{m-l+1}{n-l+2} + \frac{m}{n+1} - 1\right).$$

- If $m = n = 2$, conditions are $e/d > -1/3$ and $e/d > -1/6$.

Contract with Local or Central Authorities?

- Suppose D can choose between contracting with districts or activating and contracting with the central government
- Contracting with a (unique) central authority gives the "first best", but this is not necessarily best for D.
- Suppose there is only two districts (A and B) and potentially a central authority (C)
- Contracting with the districts reduces x if and only if $e/d < -1/3$.
- Contracting with the districts is better for D if and only if $e/d < -1/6$.
- A+B prefer decentralized contracts if $e/d \in (-0.16, 5.50)$.

Example with n=m=2



CONCLUSIONS

Contracts: Takeaways