Carbon sanctuaries and development: preserving tropical forests in a rural vs diversified economy

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Motivation

- Agricultural expansion implies deforestation through land conversion
- Deforesting is responsible for large GHG emissions and constitutes the main source of emissions for forest-abundant developing countries
- Developing countries will reduce their emissions only if they are compensated for the opportunity costs: REDD mechanism (Reduced Emissions from Deforestation and Degradation)
- This notion of opportunity costs encompasses two potential meanings: either making part of the rural labor force idle or shifting it toward less land dependent sectors which are also less profitable

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- Using a model where deforestation is induced by trade and where
  - Farmers allocate their unit labor between land clearing or maintenance and production (and harvesting NTFPs)
  - Two-sector growth model (agriculture, industry) with two dynamics on specific factors (land, capital)
- we compare the costs of two international transfer mechanisms
  - **Untied mechanism** that reduces the amount of land per rural worker
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Deforestation for agricultural purpose

- Land allocation between forest and agricultural use:
  - land endowment normalized to $\bar{n}$ units
  - $\bar{n} - n_t$ lands left in forest, n_t agricultural land at date t
  - initially, large forest
- At individual level, representative farmer allocates her one unit of labor between farming and maintaining/clearing land
  - Production function: $f(\ell_{it}^a, n_{it}) = n_{it}^{\theta}(\ell_{it}^a)^{1-\theta}$
  - Individual land dynamics: $n_{it} = \phi \ell_{it}^d + (1-\gamma) n_{it-1}$

    where $\phi > 0$: marginal productivity of labor in clearing land
    $0 < \gamma < 1$: land degradation in the absence of maintenance (biological growth of forest stock)
- Facing a credit constraint, farmers do not optimize their returns inter-temporally when deciding on clearing land.

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Two-sectors economy

- Given the available technology, each farmer deforests until he owns $n^* = \frac{\theta\phi}{1-\theta(1-\gamma)} < \bar{n}$ acres.
- At the aggregate level, L_t farmers can
  - increase the total agricultural land: $n_t = \sum_i n_{it} = \theta\phi L_t + \theta(1-\gamma)n_{t-1}$
  - produce: $y_{at} = \kappa n_t$, where $\kappa \equiv [(1-\theta)/(\phi\theta)]^{1-\theta}$ per acre yield
- Manufacturing sector with a specific factor, capital
  - Production: $y_{mt} = G(k_t, L_{mt}) = L_{mt}^{\alpha} k_t^{1-\alpha}, \;\; 0 < \alpha < 1$
  - Investment I_t increases the stock of capital, given the rate of depreciation δ: $k_{t+1} = I_t + (1-\delta)k_t$
- Constant total labor force: $L_t + L_{mt} = 1, \;\; \forall t$

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Trade-induced deforestation

- Whereas the forest-abundant economy is diversified in autarky (preferences for both goods), trade liberalization increases deforestation if the economy has a comparative advantage in agriculture
- Given world price p, the social planner maximizes the present value of national product minus capital investment:
  $V(k_t, n_{t-1}) = \max_{L_t, I_t} \{p\kappa n_t + G(k_t, 1 - L_t) - I_t + \beta V(k_{t+1}, n_t)\}$

Proposition

When the economy opens to trade, it stays diversified only if $p = p_d$, where $p_d \equiv \alpha[(1 - \beta\theta(1 - \gamma))/\theta\phi\kappa]\,[(1 - \alpha)/(r + \delta)]^{(1-\alpha)/\alpha}$. Otherwise,

- *If $p > p_d$, it specializes in agriculture. The surface devoted to agriculture increases progressively toward the steady state level n^*.*
- *If $p < p_d$, it specializes in industry. The productive capital accumulates toward the steady state level $k_I = [(1 - \alpha)/(r + \delta)]^{1/\alpha}$.*

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Conditional transfer on preserving forest

- Focus on $p > p_d$: land-dependent growth
- International institution (GEF, WB) offers a transfer defined by (s_0^J, s^J) to reduce emissions from deforestation:

$$S(n_t) = s_0^J - s^J \max\{0, n_t - \hat{n}\}, \quad J = \{T, U\}$$

  - $\hat{n} \in [0, n^*]$ environmental constraint in terms of agricultural land
  - s_0^J maximum level of transfer negotiated between the institution and the developing country
  - s^J exogenous and time invariant

- Social planner's objective is modified by the transfer:
$V(k_t, n_{t-1}) =$
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Comparing two types of opportunity costs

- Tied mechanism shifts part of the labor force toward the less profitable sector
  - Once farmers have deforested $\hat{n}$ acres, incentive to stop deforesting provided by a per acre reduction in the payment: $s^T(p) = \kappa(p - p_d)/\beta$
  - Transfer depends on the discrepancy between actual world price and the relative price required for the economy to diversify
- Untied mechanism modifies the optimal allocation of rural labor between production and land maintenance: congestion effect
  - The land use constraint reduces the maintenance effort to $\hat{\ell}^d = \gamma\hat{n}/\phi$ and rural output to $\hat{y} = \hat{n}^\theta(1 - \hat{\ell}^d)^{1-\theta}$ even when the entire population is rural
  - Incentive to stop deforesting: $s^U(\hat{n}) = \frac{p}{\phi\hat{n}}\left(\frac{\phi\hat{n}}{\phi-\gamma\hat{n}}\right)^\theta(\theta\phi - \gamma\hat{n})$

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Comparing two compensation transfers

- Participation of developing country requires at least that total returns under mechanism are higher than under laissez-faire in the long run: lower bound for s_0^J

Proposition

Comparing two mechanisms for preserving $\bar{n} - \hat{n}$ acres of forest,

i/ *if $p_d < p < \alpha k_l^{1-\alpha}/(\phi\theta)$, the tied mechanism requires a smaller compensation than the untied mechanism for all $\hat{n} \in [0, n^*]$;*

ii/ *if $p > \alpha k_l^{1-\alpha}/(\phi\theta)$, we have*

a/ *the tied mechanism also requires a smaller compensation for all $\hat{n} \in [0, \hat{n}_c]$,*
b/ *the untied mechanism requires a smaller compensation for all $\hat{n} \in [\hat{n}_c, n^*]$*

where $\hat{n}_c \in (0, n^*)$ equals the congestion effect (untied mechanism) with the opportunity cost of industrial labor (tied mechanism).

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Introducing Non-Timber Forest Products (NTFPs)

- NTFPs (e.g. fuelwood, forest fruits and vegetables) play a considerable role in the livelihoods of the rural poor (Robinson, 2011)
- NTFPs creates a value to the standing forest:
  - less deforestation under laissez-faire
  - but the price above which the economy specializes in agriculture is lower
- The costs of the preservation schemes are ranked similarly depending on the world price even if NFTPs modify the levels of the policy thresholds

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Discussion

- Enforcement issues in a decentralized equilibrium
  - Untied mechanism: strong incentive to cheat and increase individual land endowment
  - Tied mechanism: reduced risk of cheating because of alternative sector occupation
- Durability of the transfer to avoid specializing in agriculture
  - To overcome this, introduce learning spillovers in the industrial sector as in the endogenous growth literature

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Concluding remarks

- Two transfers: one scheme reduces the amount of land per rural worker, whereas the other reduces the number of workers in the agricultural sector by fostering diversification
- Two opportunity costs: one corresponds to the opportunity costs of diversification whereas the other results from the congestion effect that arises in agriculture when too many workers produce on scarce lands
- Two variables play a crucial role in assessing the long term costs: the relative world price of agricultural commodities and the amount of forest to be preserved
  - If low world price, the tied mechanism is cost efficient whatever the environmental target
  - If high world price, the tied mechanism is cost efficient only if the stock of preserved forest is large, otherwise the untied mechanism performs better

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