On the palm oil - biodiversity tradeoff: Environmental performance of smallholder producers

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Palm oil boom: Economic success and ecological desaster

![Image of palm oil products and a palm oil plantation]

<table>
<thead>
<tr>
<th>Year</th>
<th>Thousand ha</th>
<th>Tonnes per ha</th>
</tr>
</thead>
<tbody>
<tr>
<td>1960</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>1980</td>
<td>2500</td>
<td>20</td>
</tr>
<tr>
<td>2000</td>
<td>5000</td>
<td>40</td>
</tr>
<tr>
<td>2020</td>
<td>7500</td>
<td>60</td>
</tr>
</tbody>
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Area harvested - Yield

AAEA 2021 Meeting Austin
Palm oil - Biodiversity
Introduction
Palm oil in Indonesia: Developmental success & ecological disaster

Figure 1: Forest area over time

Figure 2: Food insecurity over time

(FAOSTAT, 2020)
Research gaps & questions

What we do know...
- Biodiversity threatened in Indonesia
- Macro relationships
- Trade-offs in large estates
- Mosaic-type spatial arrangements of smallholders: exceptional opportunities for biodiversity conservation
- Smallholders provide 40% of palm oil output
- Yields are low, expansion driven

What we do not know...
- Micro-level trade-offs
- Smallholders’ environmental performance
- How to conserve biodiversity during commodity booms?
Data

- Ongoing oil palm farm survey in Jambi province of Sumatra, Indonesia
- Short unbalanced panel of 3 waves (2012, 2015, 2018)
- 123 observations
- Conventional input-output, socio economics, agricultural practices, plot plant species abundance and richness data
Restricted (hybrid) hyperbolic distance function

- Environmental **restricted** hyperbolic distance function

\[
D_R(\bar{x}, x, y, b) = \min \left\{ \theta : \left( \bar{x}, x\theta, \frac{y}{\theta}, b\theta \right) \in T \right\},
\]

hybrid of enhanced hyperbolic and hyperbolic functions

- \( \bar{x} \) Fixed inputs (\( \cdot \))
- \( x \) Variable inputs (\( \downarrow \))
- \( y \) Good output (\( \uparrow \))
- \( b \) Bad output (\( \downarrow \))

- **Shadow price** of biodiversity conservation

Figure 3: Environmental hyperbolic distance function
Mean efficiency: 0.78
Potential good output expansion: 28%
Potential bad output contraction: 22%

Manual and chemical weeding among drivers
Policy scenarios & Shadow prices

- Eliminating weeding: 3% (19) more species and 2.4% more palm oil (practice based PES)
- Abating biodiversity loss by one species amounts to 340$ per farm, 173$ per ha or 16% of annual farm palm oil income, on average
- Design PES to target
  (i) Social inclusivity of conservation
  (ii) Uniform biodiversity
  (iii) Cost minimizing
Results and policy implications

- Substantial environmental inefficiency among smallholders
- Sizable conservation potential in smallholder sectors
- Abatement cost for conserving are high
- Practice based PES to lower abatement cost without trade-off
- Outcome-PES to incentivize conservation require target dimension
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Thank you for your attention!
Back up
Empirical specification (translog hyperbolic production function)

- **Restricted hyperbolic** distance function

\[-\ln y_i = \alpha_0 + \sum_{k=1}^{3} \alpha_k \ln(x_{ki}) + \alpha_4 \ln(x_{4i}^*) + \beta_1 \ln(b_i^*) + \sum_{k=1}^{3} \beta_{1k} \ln(b_i^*) \ln(x_i)\]

\[+ \beta_{14} \ln(b_i^*) \ln(x_{4i}^*) + \frac{1}{2} \sum_{k=1}^{3} \sum_{l=1}^{3} \alpha_{kl} \ln(x_{ki}) \ln(x_{li}) + \frac{1}{2} \sum_{k=1}^{3} \alpha_{k4} \ln(x_{k}^*) \ln(x_4) +\]

\[+ \frac{1}{2} \alpha_{44} \ln(x_i)^2 + \frac{1}{2} \beta_{11} \ln(b_i^*)^2 + \rho_0 t_i + u_i + v_i, \quad (2)\]

- \(y_i\): Oil palm, \(b_i\): Biodiversity loss, \(x_i\): Inputs, \(b_i^* = y_i \times b_i\), \(x_i^* = \frac{x_i}{y_i}\)
Empirical specification (Inefficiency model)

For the error component $u_i + v_i$ we assume

- Homoskedastic symmetric noise:
  
  $$v_i \sim N(0, \sigma_v^2) \quad (3)$$

- Heteroskedastic one sided inefficiency:
  
  $$u_i \sim N^+(\mu, \sigma_{u,i}^2) \quad (4)$$

and

$$\sigma_{u,i}^2 = \exp(\tau'z_i) \quad (5)$$