Indonesian Agricultural Research, Agricultural Incentives, and Productivity Growth

Causes and Consequences of Global Agricultural Productivity Growth
Washington, D.C., May 11-12, 2010

Nicholas Rada and Keith Fuglie, ERS/USDA
Steve Buccola, Oregon State University
Agricultural Export Values, 1975-2007

- FAOSTAT (2009)
Agricultural Incentives
Nominal rates of assistance, 1985-2005

- Anderson et al. (2008). Data are available at www.worldbank.org/agdistortions
Research Questions

- What has been Indonesia’s agricultural technology growth?
- How does technology change alter farm output choices & input factors?
- Has Indonesia’s agricultural R&D contributed to technology growth?
- What was the impact of the shift in Indonesia’s nominal rates of assistance on technology growth?
Agricultural Incentives

Nominal rates of assistance, 1985-2005

- Anderson et al. (2008). Data are available at www.worldbank.org/agdistortions
Agricultural Research

- Agricultural Research began in early 1800s by the Dutch colonial authorities

- Established Research Stations:
  - Botanical Garden, Bogor, West Java (1817)
  - Sugarcane (1885)
  - Coffee & Cacao (1901)
  - Tea (1902)
  - Tobacco (1907)
  - Rubber (1916)

- Established Department of Agriculture (1905)
Scientific Decay & Revival

<table>
<thead>
<tr>
<th>Period</th>
<th>Key Events</th>
</tr>
</thead>
<tbody>
<tr>
<td>WW II (1942-1945)</td>
<td></td>
</tr>
<tr>
<td>War of Independence</td>
<td></td>
</tr>
<tr>
<td>(1945-1949)</td>
<td></td>
</tr>
<tr>
<td>Nationalization</td>
<td>Nationalization of foreign owned plantations (1957)</td>
</tr>
<tr>
<td>Central Agricultural</td>
<td>Central Agricultural Research Station employed 1 Ph.D. trained scientist</td>
</tr>
<tr>
<td>Station employed</td>
<td>(1966)</td>
</tr>
<tr>
<td>1 Ph.D. trained</td>
<td>van der Eng (1996)</td>
</tr>
<tr>
<td>scientist (1966)</td>
<td></td>
</tr>
<tr>
<td>President Suharto</td>
<td>President Suharto (1966)</td>
</tr>
<tr>
<td>(1966)</td>
<td>– Macroeconomic stability</td>
</tr>
<tr>
<td></td>
<td>– Food self-sufficiency</td>
</tr>
<tr>
<td>Established the</td>
<td>Established the Agency for Agricultural Research &amp; Development (AARD) (1974)</td>
</tr>
<tr>
<td>Agency for</td>
<td>– 11 Ph.D.s</td>
</tr>
<tr>
<td>Agricultural</td>
<td>– 33 M.Sc.s</td>
</tr>
<tr>
<td>Research &amp;</td>
<td>– 294 B.Sc.s</td>
</tr>
<tr>
<td>Development (AARD)</td>
<td>(1974)</td>
</tr>
<tr>
<td>(1974)</td>
<td></td>
</tr>
</tbody>
</table>
Indonesian Agricultural History

- World’s largest rice importer in mid-1960s
- Upon achieving near rice self-sufficiency, Government policy shifted toward an industry-first policy by mid-1980s
- Periodic currency devaluations (1978, 1983, 1986) and economic deregulation mark transition
Indonesian Agricultural History

Impact of 1997 Asian financial crisis:

• Plunged 1998 GDP growth rate to -13%

• 1998 agricultural export value fell to -18.8%

• Required IMF aid to regain macroeconomic stability
  o reduce food-crop tariffs
  o deregulate inter-provincial movement of agricultural commodities
  o break BULOG’s monopoly over rice, wheat, soybeans, and sugar
  o eliminate foreign investment restrictions
Model: Stochastic output distance frontier

- Multiple outputs:
  - Annual crops
  - Perennial crops
  - Livestock

- Stochastic frontier:
  - Account for stochasticity
  - Account for technical inefficiencies
Technical Efficiency

What is technical efficiency?

• Relative infra-frontier residuals, or the proximity of a farm’s operations to its own frontiers

Why is it important?

• Typical composed errors confound statistical noise and data measurement error with technical inefficiencies
Econometric Approach

- How do we measure technical efficiency?

- How do we explain technical efficiency?

\[ E \left[ \exp(-u_{it}) \mid \varepsilon_{it} \right] \]

- (Battese and Coelli 1988)

\[ u_{it} \sim N^+(0, \sigma^2_{u,it}) \]
Econometric Approach

• In what form?

\[ u_{it} = g(\ln z_{ait}; \Omega)\eta_{it}, \ a = 1 \ldots A \]


• In what parametric specification?

\[ g(\ln z_{ait}; \Omega)\eta_{it} = \exp(\ln z_{ait}; \Omega)\eta_{it} \]
Indonesian Data

- Panel data covering 22 Provinces across 21 years (1985-2005)

- 50 outputs
  - 3 Fisher output indices (Annual crops, Perennial crops, and Livestock)

- 6 inputs
  - 3 Fisher input indices (capital, labor, and materials)

- An agricultural research stock variable

- 3 exogenous policy variables (agricultural developmental expenditures, road density, and literacy rate)

- Indonesia’s nominal rate of assistance (NRA)
Model: Stochastic output distance frontier

\[ D_O(x_{kit}, y_{jit}, R_{it}, V_{it}, NRA_{it}, Road_{it}, t, \beta) = \exp(\nu_{it} - u_{it}) \]

\[ \nu_{it} \sim iid \ N(0, \sigma^2_v) \]
\[ u_{it} \sim N^+(0, \sigma^2_u) \]
\[ \sigma_{vu} = 0 \]

\[ h(\ln x_{kit}, \ln y_{jit}, \ln R_{it}, NRA_{it}, \ln V_{it}, \ln Road_{it}, t, \beta) \]
\[ e^{\nu_{it}} \]
\[ e^{\nu_{it}} = e^{(-u_{it})} \]
Model: Stochastic Output Distance Frontier

- The estimable model:

\[
-ln y_{mit} = h(ln x_{kit}, ln y_{jit}^*, ln R_{it}, NRA_{it}, ln V_{it}, ln Road_{it}, t, \beta) + g(ln z_{ait}, \Omega)\eta_{it} - \nu_{it},
\]

\[
= h(ln x_{kit}, ln y_{jit}^*, ln R_{it}, NRA_{it}, ln V_{it}, ln Road_{it}, t, \beta) + \exp\{ln z_{ait}, \Omega\} + \varepsilon_{it},
\]

\[
D_O (ln x_{kit}, ln y_{jit}^*, t, \beta) = TL(P_i, ln x_{kit}, ln y_{jit}^*, t; \beta) + \beta ln R_{it} + \beta t ln R_{it}
\]

\[
+ \beta ln NRA_{it} + \beta t ln NRA_{it} + \beta ln V_{it} + \beta ln Road_{it}
\]
Model: Stochastic Output Distance Frontier

• The estimable model:

\[-\ln y_{mit} = h(\ln x_{kit}, \ln y^*_{jit}, \ln R_{it}, \ln NRA_{it}, \ln V_{it}, \ln Road_{it}, t, \beta) + g(\ln z_{ait}; \Omega)\eta_{it} - v_{it},\]

\[= h(\ln x_{kit}, \ln y^*_{jit}, \ln R_{it}, \ln NRA_{it}, \ln V_{it}, \ln Road_{it}, t, \beta) + \exp\{\ln z_{ait}; \Omega\} + \varepsilon_{it},\]

\[D_O (\ln x_{kit}, \ln y^*_{jit}, t, \beta) = TL(P_i, \ln x_{kit}, \ln y^*_{jit}, t; \beta) + \beta \ln R_{it} + \beta t \ln R_{it} + \beta \ln NRA_{it} + \beta t \ln NRA_{it} + \beta \ln V_{it} + \beta \ln Road_{it}\]

\[\ln \sigma^2_{u, it} = \ln \sigma^2_\eta + 2 \ln z_{ait}; \Omega\]
Agricultural Research Stock

\[ R_\text{it} = 0.005 \cdot \text{AgExp}_{i,t=-1} + 0.01 \cdot \text{AgExp}_{i,t=-2} + 0.02 \cdot \text{AgExp}_{i,t=-3} + 0.03 \cdot \text{AgExp}_{i,t=-4} + 0.045 \cdot \text{AgExp}_{i,t=-5} + 0.06 \cdot \text{AgExp}_{i,t=-6} + 0.08 \cdot \text{AgExp}_{i,t=-7,-8,-9,-10,-11,-12,-13,-14} + 0.06 \cdot \text{AgExp}_{i,t=-15} + 0.0323 \cdot \text{AgExp}_{i,t=-16,-17,-18,-19} \]  

- Huffman and Evenson (1993)
### Selected Estimated Coefficients

| Dep. Var. | Coefficients | P>|Z| |
|-----------|--------------|-----|
| -Perennials |              |     |
| R         | -0.0086747   | 0   |
| NRA       | -0.1962624   | 0.037 |
| V         | -0.0528759   | 0   |
| Road      | -0.0092789   | 0.606 |
| t·R       | 0.0006779    | 0.001 |
| t·NRA     | 0.0120223    | 0.079 |

\[
\ln \sigma^2_{u,it}
\]

|                | Coefficients | P>|Z| |
|----------------|--------------|-----|
| V              | -1.050504    | 0   |
| Road           | -0.5453968   | 0.008 |
| Literacy       | 24.39787     | 0   |
| Constant       | -87.93563    | 0   |

N=462; Log likelihood: 646.8
Measuring Technology Growth

\[
\frac{d \ln Y_{jit}}{dt} = \frac{\partial \ln Y_{jit}}{\partial t} + \frac{\partial \ln Y_{jit}}{\partial \ln R_{it}} \frac{d \ln R_{it}}{dt} + \frac{\partial \ln Y_{jit}}{\partial NRA_{it}} \frac{d NRA_{it}}{dt}
\]
Agricultural Incentives

Nominal rates of assistance, 1985-2005
‘Anti-Agriculture’ Period, 1985-1997

<table>
<thead>
<tr>
<th></th>
<th>Informal Technical Change Rates (TCR)</th>
<th>Output elasticity of agricultural research</th>
<th>Time rate of change in agricultural research</th>
<th>Marginal Impact of NRA</th>
<th>Time rate of change in NRA</th>
<th>Total NRA Impacts</th>
<th>Formal TCR</th>
<th>Revenue Share Weights</th>
<th>Aggregated TCR</th>
</tr>
</thead>
<tbody>
<tr>
<td>Perennials</td>
<td>4.49%</td>
<td>0.00%</td>
<td>35.42%</td>
<td>-0.36%</td>
<td>4.17%</td>
<td>22.4%</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Livestock</td>
<td>3.43%</td>
<td>0.00%</td>
<td>6.24%</td>
<td>27.06%</td>
<td>-1.02%</td>
<td>-0.28%</td>
<td>3.19%</td>
<td>10.6%</td>
<td>2.14%</td>
</tr>
<tr>
<td>Annuals</td>
<td>1.39%</td>
<td>0.00%</td>
<td>10.99%</td>
<td>-0.11%</td>
<td>1.29%</td>
<td>67.0%</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

\[
\frac{\partial \ln Y_{jit}}{\partial t} + \frac{\partial \ln Y_{jit}}{\partial \ln R_{it}} \frac{d \ln R_{it}}{dt} + \frac{\partial \ln Y_{jit}}{\partial \ln \text{NRA}_{it}} \frac{d \text{NRA}_{it}}{dt} = \frac{d \ln Y_{jit}}{dt}
\]
‘Pro-Agriculture’ Period, 1998-2005

<table>
<thead>
<tr>
<th></th>
<th>Informal Technical Change Rates (TCR)</th>
<th>Output elasticity of agricultural research</th>
<th>Time rate of change in agricultural research</th>
<th>Marginal Impact of NRA</th>
<th>Time rate of change in NRA</th>
<th>Total NRA Impacts</th>
<th>Formal TCR</th>
<th>Revenue Share Weights</th>
<th>Aggregated TCR</th>
</tr>
</thead>
<tbody>
<tr>
<td>Perennials</td>
<td>4.49%</td>
<td>0.00%</td>
<td>35.42%</td>
<td>0.95%</td>
<td>5.48%</td>
<td>22.4%</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Livestock</td>
<td>3.43%</td>
<td>0.00%</td>
<td>4.91%</td>
<td>27.06%</td>
<td>2.69%</td>
<td>4.18%</td>
<td>10.6%</td>
<td>2.81%</td>
<td></td>
</tr>
<tr>
<td>Annuals</td>
<td>1.39%</td>
<td>0.00%</td>
<td>10.99%</td>
<td>0.30%</td>
<td>1.70%</td>
<td>67.0%</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

\[
\frac{\partial \ln Y_{jit}}{\partial t} + \frac{\partial \ln Y_{jit}}{\partial \ln R_{it}} \frac{d \ln R_{it}}{dt} + \frac{\partial \ln Y_{jit}}{\partial \ln \Delta \text{NRA}_{it}} \frac{d \ln \Delta \text{NRA}_{it}}{dt} = \frac{d \ln Y_{jit}}{dt}
\]
What then has been the net average annual impact of improving Indonesia’s agricultural NRA?

• 1.31% on perennial crop technology growth
• 1.01% on livestock technology growth
• 0.41% on annual crop technology growth

• In terms of the impact on the entire agricultural sector: 0.67%
How Did Technology Growth Alter Output Choices & Input Factors?

\[ RB_{ij} \equiv \partial \ln D_{O,Y_i} (y_j, x_k, t) / \partial t - \partial \ln D_{O,Y_i} (y_j, x_k, t) / \partial t, \quad i \neq j, \]

\[ RB_{kh} \equiv \partial \ln D_{O,X_k} (y_j, x_k, t) / \partial t - \partial \ln D_{O,X_h} (y_j, x_k, t) / \partial t, \quad k \neq h, \]

\[ RB_j = \sum_{j \neq i}^M R_j RB_{ij}, \quad RB_k = \sum_{k \neq h}^N R_k RB_{kh} \]
How Did Technology Growth Alter Output Choices & Input Factors?
How Did Technology Growth Alter Output Choices & Input Factors?
## Technical Change Bias:

<table>
<thead>
<tr>
<th>Input Bias</th>
<th>$RB_k$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Capital</td>
<td>0.08%</td>
</tr>
<tr>
<td>Intermediates</td>
<td>0.70%</td>
</tr>
<tr>
<td>Labor</td>
<td>-0.55%</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Output Bias</th>
<th>$RB_i$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Annuals</td>
<td>0.35%</td>
</tr>
<tr>
<td>Perennials</td>
<td>-0.87%</td>
</tr>
<tr>
<td>Livestock</td>
<td>-0.37%</td>
</tr>
</tbody>
</table>
What Has Been the Total Factor Productivity Growth?

- If we assume TFP growth = Technical Change + Efficiency Change, then:

<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Aggregated TCR</td>
<td>Aggregated TCR</td>
</tr>
<tr>
<td>Technical Efficiency Change</td>
<td>Technical Efficiency Change</td>
</tr>
<tr>
<td>Total Factor Productivity Growth</td>
<td>Total Factor Productivity Growth</td>
</tr>
<tr>
<td>2.14%</td>
<td>2.81%</td>
</tr>
<tr>
<td>0.24%</td>
<td>-0.86%</td>
</tr>
<tr>
<td>2.38%</td>
<td>1.95%</td>
</tr>
</tbody>
</table>

*Mean T.E. level = 96.9%  
*Mean T.E. level = 94.4%
In Conclusion

• Technology Growth has been nearly Hicks-neutral.

• Perennial crop technology growth has expanded at the greatest rate.

• Public agricultural research has not been found to impact technology growth.

• Indonesia’s trade liberalization, and improvement in agricultural NRA, significantly impacted technology growth.

• Greater growth comes at the cost of greater inequality.
What then has been the **net average annual impact** of improving agricultural incentives between 1985 and 2005?

<table>
<thead>
<tr>
<th></th>
<th>Informal Technical Change Rates (TCR)</th>
<th>Output elasticity of agricultural research</th>
<th>Time rate change in agricultural research</th>
<th>Marginal Impact of Trade Liberalization</th>
<th>Time rate change in NRA</th>
<th>Total NRA Impacts</th>
<th>Formal TCR</th>
<th>Revenue Share Weights</th>
<th>Aggregated TCR</th>
<th>Technical Efficiency Change</th>
<th>Total Factor Productivity Growth</th>
</tr>
</thead>
<tbody>
<tr>
<td>Perennials</td>
<td>4.49%</td>
<td>0.00%</td>
<td>35.42%</td>
<td></td>
<td>0.24%</td>
<td>4.77%</td>
<td>22.4%</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Livestock</td>
<td>3.43%</td>
<td>0.00%</td>
<td>5.65%</td>
<td>27.06%</td>
<td>0.69%</td>
<td>0.19%</td>
<td>3.65%</td>
<td>10.6%</td>
<td>2.45%</td>
<td>-0.20%</td>
<td>2.25%</td>
</tr>
<tr>
<td>Annuals</td>
<td>1.39%</td>
<td>0.00%</td>
<td>10.99%</td>
<td></td>
<td>0.08%</td>
<td>1.48%</td>
<td>67.0%</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Econometric Approach

• Characterize stochastic frontier as:

\[ e^{h(\ln x_{kit}, \ln y_{jit}, t, \beta)} = e^{(\nu_{it} - g(\ln z_{ait}; \Omega)\eta_{it})}. \]

• Specify an exponential form:

\[ u_{it} = g(\ln z_{ait}; \Omega)\eta_{it} = \exp(\ln z_{ait}'\Omega)\eta_{it}, \]

\[ e^{h(\ln x_{kit}, \ln y_{jit}, t, \beta)} = e^{(\nu_{it} - \exp(\ln z_{ait}'\Omega)\eta_{it})}. \]

• The first two moments of inefficiency error are:

\[ E(u_{it}) = \exp\left\{ \ln z_{ait}'\Omega \right\} > 0 \]

\[ V(u_{it}) = \sigma_{u,it}^2 = g(\ln z_{ait}, \Omega)^2 \sigma_\eta^2 = \exp\left\{ 2 \ln z_{ait}'\Omega \right\} \sigma_\eta^2 \]
Econometric Approach

• Estimable Model:

\[-\ln y_{mit} = h(\ln x_{kit}, \ln y^*_jit, t, \beta) + g(\ln z_{ait}; \Omega)\eta_{it} - \nu_{it},\]
\[= h(\ln x_{kit}, \ln y^*_jit, t, \beta) + \exp \{\ln z_{ait}; \Omega\} + \varepsilon_{it},\]

where

\[\varepsilon_{it} = -\nu_{it} + \exp \{\ln z_{ait}; \Omega\}(\eta_{it} - 1).\]

• The variance of my estimable model is

\[\text{Var}(-\ln y_{mit}) = \exp\{2 \ln z_{ait}; \Omega\}\sigma^2_\eta + \sigma^2_v\]

• Two moments of composed error:

\[E(\varepsilon_{it}) = 0,\]
\[V(\varepsilon_{it}) = \sigma^2_v + \exp\{2 \ln z_{ait}; \Omega\}\sigma^2_\eta,\]
Econometric Approach

• Likelihood function:

\[
\ln L = \text{constant} - \frac{1}{2} \sum_i \ln \left[ g(\ln z_{ait}; \Omega) + \sigma_v^2 \right] + \sum_i \ln \Phi \left( -\frac{\varepsilon_{it} \lambda_{it}}{\sigma_{it}} \right) - \frac{1}{2} \sum_i \frac{\varepsilon_{it}^2}{\sigma_{it}^2}.
\]

• Variance Parameters:

\[
\sigma_{it}^2 = \sigma_v^2 + \sigma_{u,it}^2 = \sigma_v^2 + g(\ln z_{ait}; \Omega),
\]

\[
\lambda_{it} = \frac{\sigma_{u,it}}{\sigma_v} = \frac{\sqrt{g(\ln z_{ait}; \Omega)}}{\sigma_v}.
\]
# AARD Funding

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Ag. GDP (billions)</td>
<td>60.3</td>
<td>88.6</td>
<td>110.3</td>
</tr>
<tr>
<td>Ag. Research</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>expenditures % of</td>
<td>0.3 %</td>
<td>0.3 %</td>
<td>0.2 %</td>
</tr>
<tr>
<td>Ag. GDP</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ag. Research spending</td>
<td>10.7</td>
<td>10.6</td>
<td>9.4</td>
</tr>
<tr>
<td>per farm</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

- Fuglie and Piggott (2006)