Indonesian Agricultural Research, Agricultural Incentives, and Productivity Growth

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

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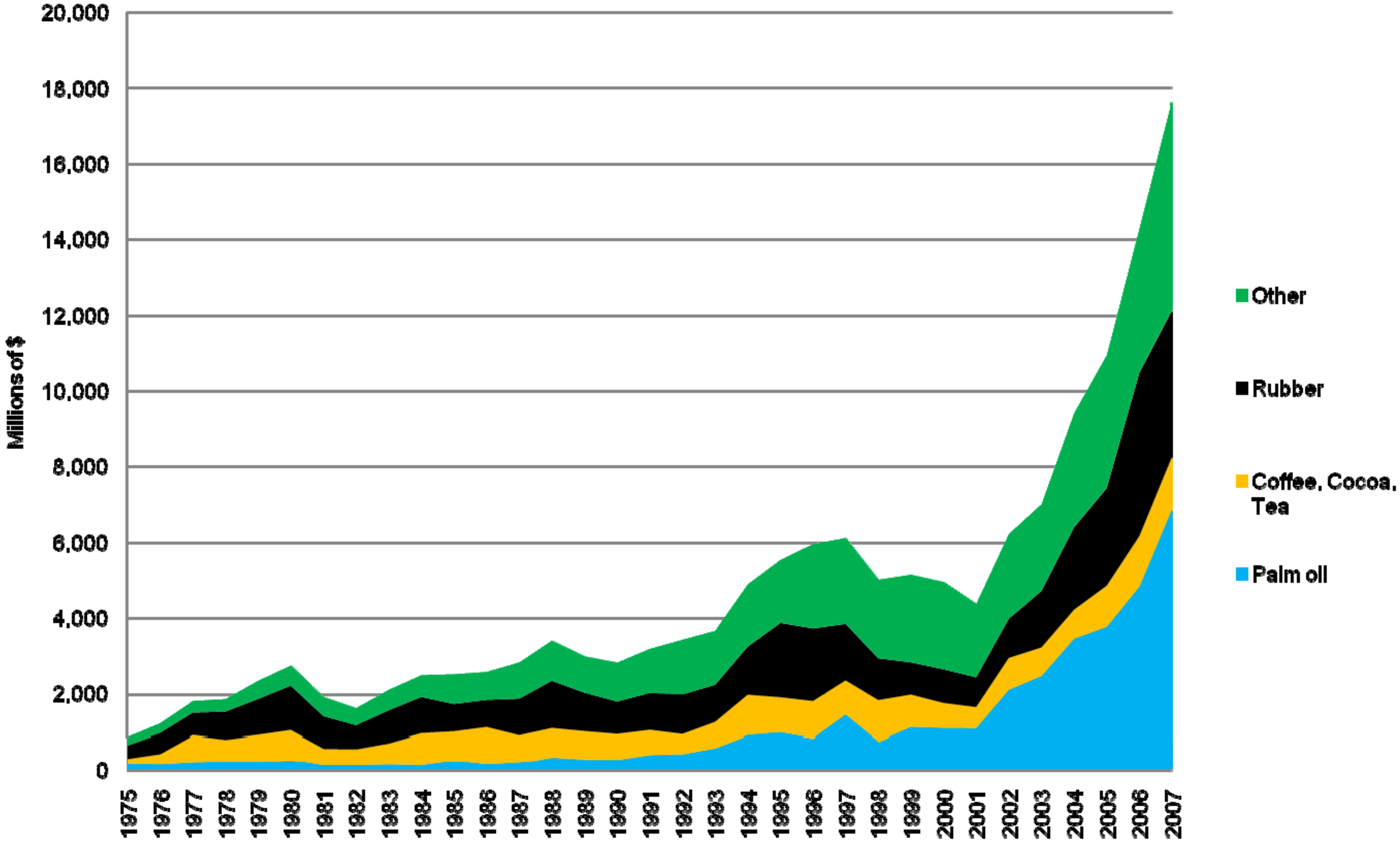
Agricultural Export Values, 1975-2007



- FAOSTAT (2009)

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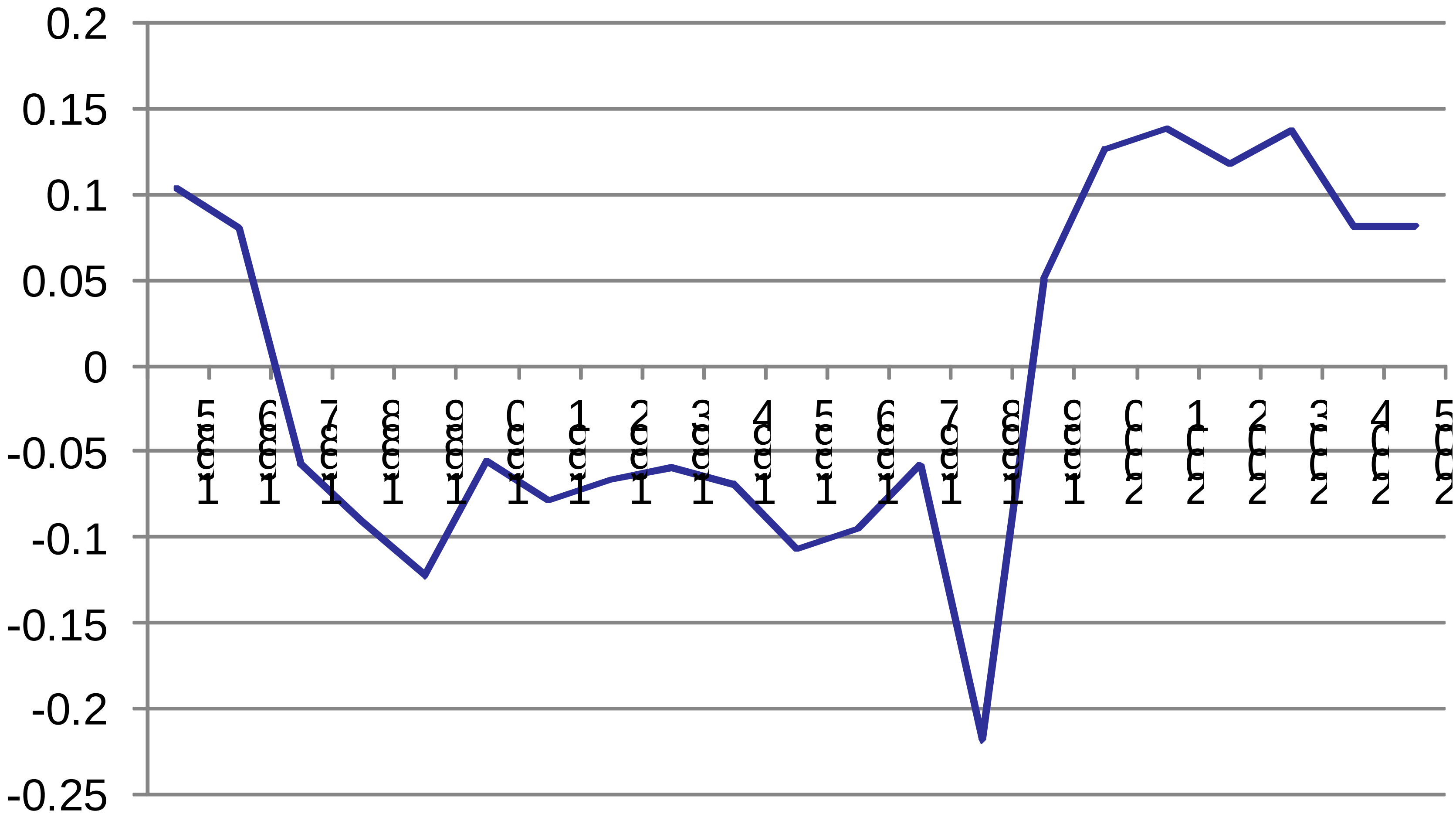
Agricultural Incentives

Nominal rates of assistance, 1985-2005



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

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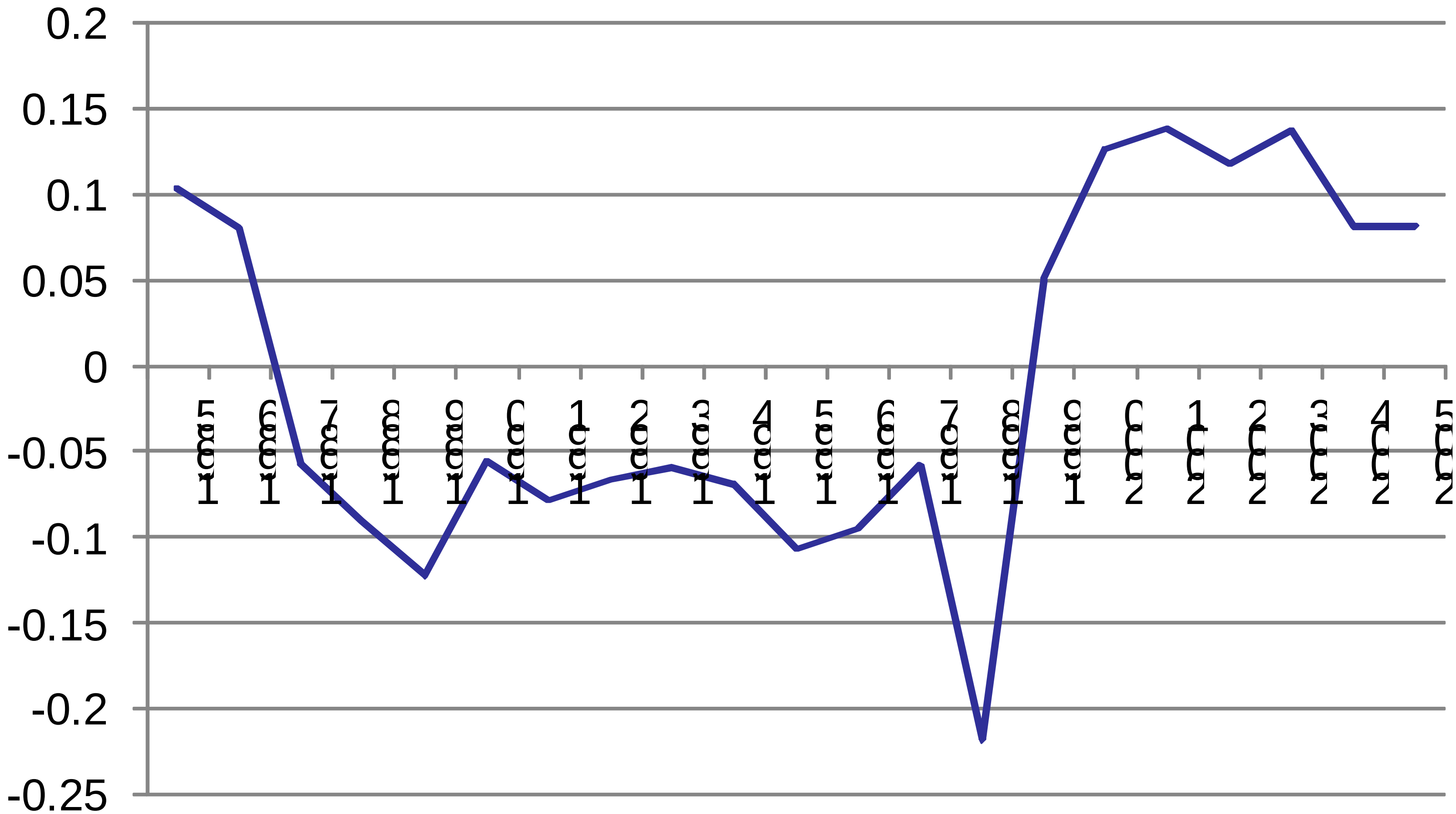
Research Questions

- 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



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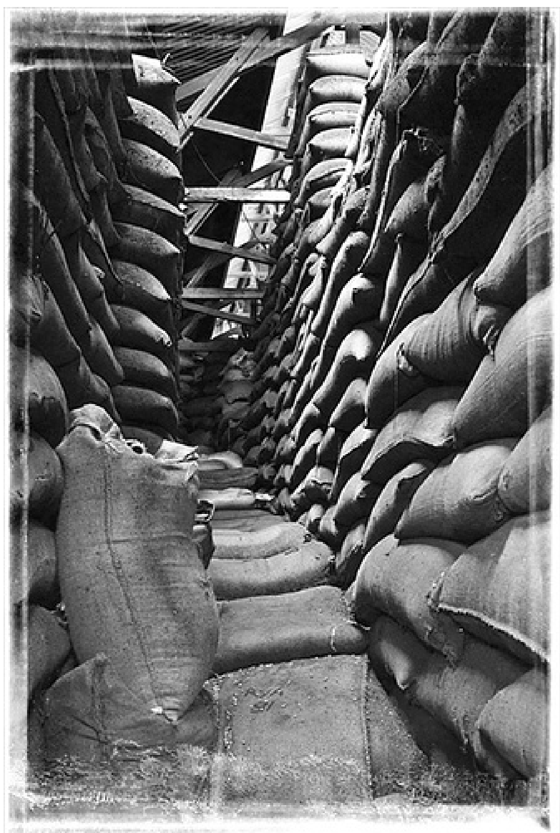
Agricultural Research

- 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

- WW II (1942-1945)
- War of Independence (1945-1949)
- Nationalization of foreign owned plantations (1957)
- Central Agricultural Research Station employed 1 Ph.D. trained scientist (1966) - van der Eng (1996)

- President Suharto (1966)
  - Macroeconomic stability
  - Food self-sufficiency
- Established the Agency for Agricultural Research & Development (AARD) (1974)
  - 11 Ph.D.s
  - 33 M.Sc.s
  - 294 B.Sc.s

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

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Indonesian Agricultural History

<u>Impact of 1997 Asian financial crisis:</u>

- Plunged 1998 GDP growth rate to -13%
- 1998 agricultural export value fell to -18.8%
- Required IMF aid to regain macroeconomic stability
  - reduce food-crop tariffs
  - deregulate inter-provincial movement of agricultural commodities
  - break BULOG's monopoly over rice, wheat, soybeans, and sugar
  - eliminate foreign investment restrictions

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Model: Stochastic output distance frontier

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

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

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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?

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

- (Battese and Coelli 1988)

- How do we explain technical efficiency?

$$u_{it} \sim N^{+}(0, \sigma^2_{u,it})$$

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Econometric Approach

- In what form?

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

-(Simar, Lovell, and Vanden Eeckaut (1994); Caudill, Ford, and Gropper (1995); Kumbhakar and Lovell (2000)

- 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)

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Model: Stochastic output distance frontier

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

$$v_{it} \sim iid \;\; N(0, \sigma_v^2)$$
$$u_{it} \sim \; N^+(0, \sigma_u^2)$$
$$\sigma_{vu} = 0$$

$$\frac{e^{h(\ln x_{kit}, \ln y_{jit}, \ln R_{it}, NRA_{it}, \ln V_{it}, \ln Road_{it}, t, \beta)}}{e^{v_{it}}} = e^{(-u_{it})}$$

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Model: Stochastic Output Distance Frontier

- The estimable model:

$$
\begin{aligned}
-\ln y_{mit} &= h(\ln x_{kit},\ \ln y^{*}_{jit},\ \ln R_{it},\ NRA_{it},\ \ln V_{it},\ \ln Road_{it},\ t,\ \beta) + g(\ln z_{ait};\Omega)\eta_{it} - v_{it}, \\
&= h(\ln x_{kit},\ \ln y^{*}_{jit},\ \ln R_{it},\ NRA_{it},\ \ln V_{it},\ \ln Road_{it},\ t,\ \beta) + \exp\left\{\ln z_{ait}{}'\Omega\right\} + \varepsilon_{it},
\end{aligned}
$$

$$
\begin{aligned}
D_O(\ln x_{kit}, \ln y^{*}_{jit}, t, \beta) = TL(P_i\ ,\ \ln x_{kit},\ \ln y^{*}_{jit}\ ,\ t\ ;\boldsymbol{\beta}) + \beta \ln R_{it} + \beta t \ln R_{it} \\
+ \beta \ln NRA_{it} + \beta t \ln NRA_{it} + \beta \ln V_{it} + \beta \ln Road_{it}
\end{aligned}
$$

Model: Stochastic Output Distance Frontier

- The estimable model:

$$-\ln y_{mit} = h(\ln x_{kit},\ \ln y^{*}_{jit},\ \ln R_{it},\ NRA_{it},\ \ln V_{it},\ \ln Road_{it},\ t,\ \beta) + g(\ln z_{ait};\Omega)\eta_{it} - v_{it},$$
$$= h(\ln x_{kit},\ \ln y^{*}_{jit},\ \ln R_{it},\ NRA_{it},\ \ln V_{it},\ \ln Road_{it},\ t,\ \beta) + \exp\left\{\ln z_{ait}{}'\Omega\right\} + \varepsilon_{it},$$

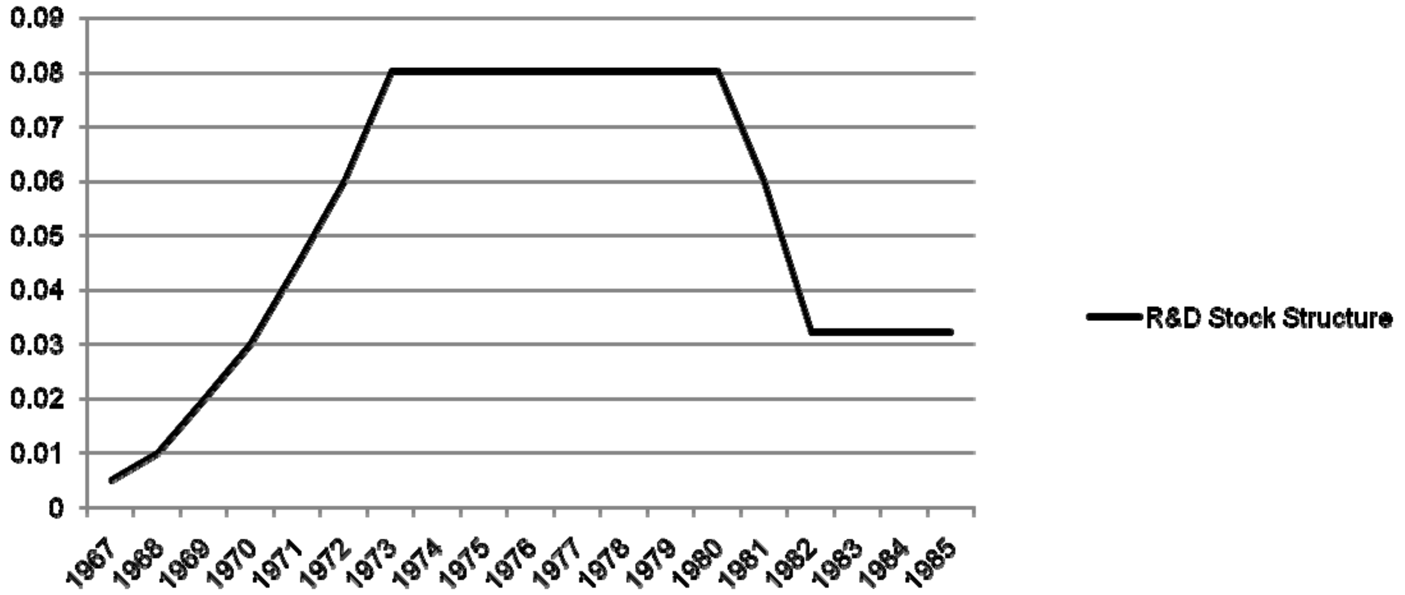
$$D_O(\ln x_{kit}, \ln y^{*}_{jit}, t, \beta) = TL(P_i\ ,\ \ln x_{kit},\ \ln y^{*}_{jit}\ ,\ t\ ;\boldsymbol{\beta}) + \beta \ln R_{it} + \beta t \ln R_{it}$$
$$+ \beta \ln NRA_{it} + \beta t \ln NRA_{it} + \beta \ln V_{it} + \beta \ln Road_{it}$$

$$\ln \sigma^2_{u,it} = \ln \sigma^2_{\eta} + 2 \ln z_{ait}{}'\Omega$$

Agricultural Research Stock

$$
\begin{aligned}
R_{it} = {} & 0.005 * AgExp_{i,t=-1} + 0.01 * AgExp_{i,t=-2} + 0.02 * AgExp_{i,t=-3} + 0.03 * AgExp_{i,t=-4} \\
& + 0.045 * AgExp_{i,t=-5} + 0.06 * AgExp_{i,t=-6} + 0.08 * AgExp_{i,t=-7,-8,-9,-10,-11,-12,-13,-14} \\
& + 0.06 * AgExp_{i,t=-15} + 0.0323 * AgExp_{i,t=-16,-17,-18,-19}
\end{aligned}
$$

- 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
$\ln \sigma^2_{u,it}$		
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

$$\frac{d\ln Y_{jit}}{dt}=\frac{\partial\ln Y_{jit}}{\partial t}+\frac{\partial\ln Y_{jit}}{\partial\ln R_{it}}\frac{d\ln R_{it}}{dt}+\frac{\partial\ln Y_{jit}}{\partial NRA_{it}}\frac{dNRA_{it}}{dt}$$

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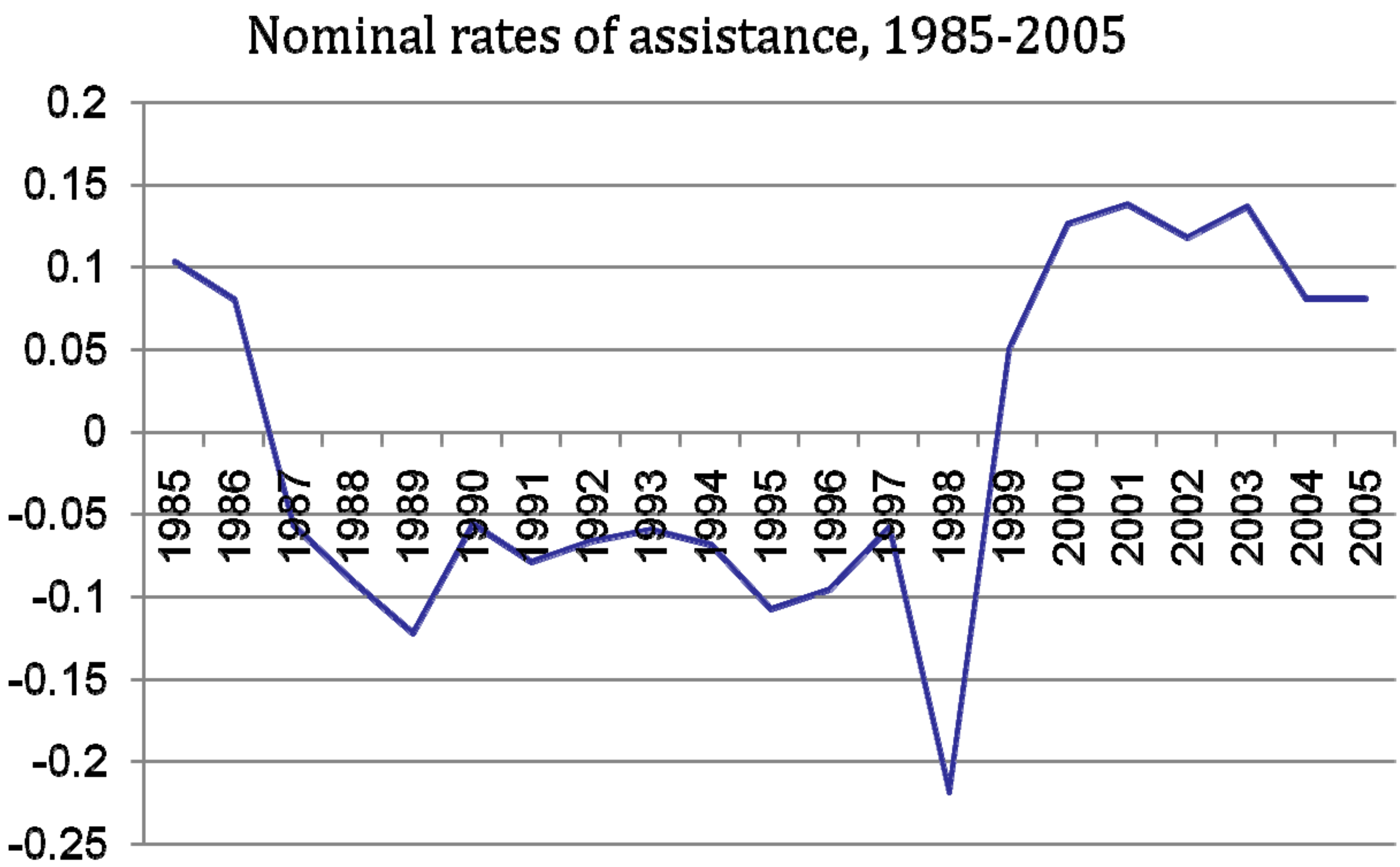
Agricultural Incentives



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‘Anti-Agriculture’ Period, 1985-1997

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

$$\frac{\partial \ln Y_{jit}}{\partial t} + \frac{\partial \ln Y_{jit}}{\partial \ln R_{it}} \frac{d \ln R_{it}}{dt} + \frac{\partial \ln Y_{jit}}{\partial NRA_{it}} \frac{dNRA_{it}}{dt} = \frac{d \ln Y_{jit}}{dt}$$

‘Pro-Agriculture’ Period, 1998-2005

	Informal Technical Change Rates (TCR)	*Output elasticity of agricultural research*	*Time rate of change in agricultural research*	*Marginal Impact of NRA*	*Time rate of change in NRA*	*Total NRA Impacts*	*Formal TCR*	*Revenue Share Weights*	*Aggregated TCR*
Perennials	4.49%	0.00%		35.42%		0.95%	5.48%	22.4%	
Livestock	3.43%	0.00%	4.91%	27.06%	2.69%	0.73%	4.18%	10.6%	2.81%
Annuals	1.39%	0.00%		10.99%		0.30%	1.70%	67.0%	

$$\frac{\partial \ln Y_{jit}}{\partial t} + \frac{\partial \ln Y_{jit}}{\partial \ln R_{it}} \frac{d \ln R_{it}}{dt} + \frac{\partial \ln Y_{jit}}{\partial NRA_{it}} \frac{dNRA_{it}}{dt} = \frac{d \ln Y_{jit}}{dt}$$

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?

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

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

$$RB_j = \sum_{j \neq i}^{M} R_j RB_{ij}, \quad RB_k = \sum_{k \neq h}^{N} R_k RB_{kh}$$

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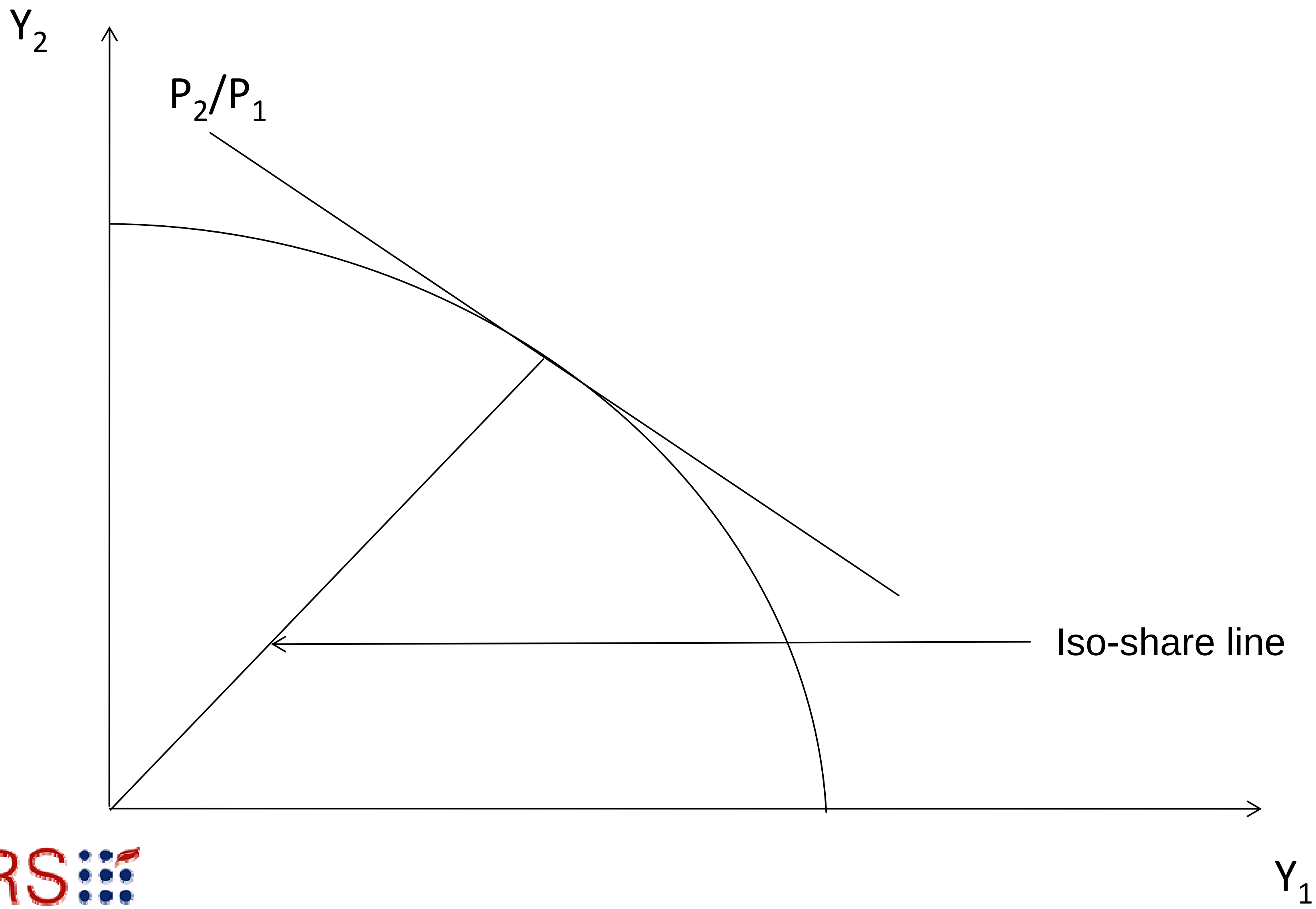
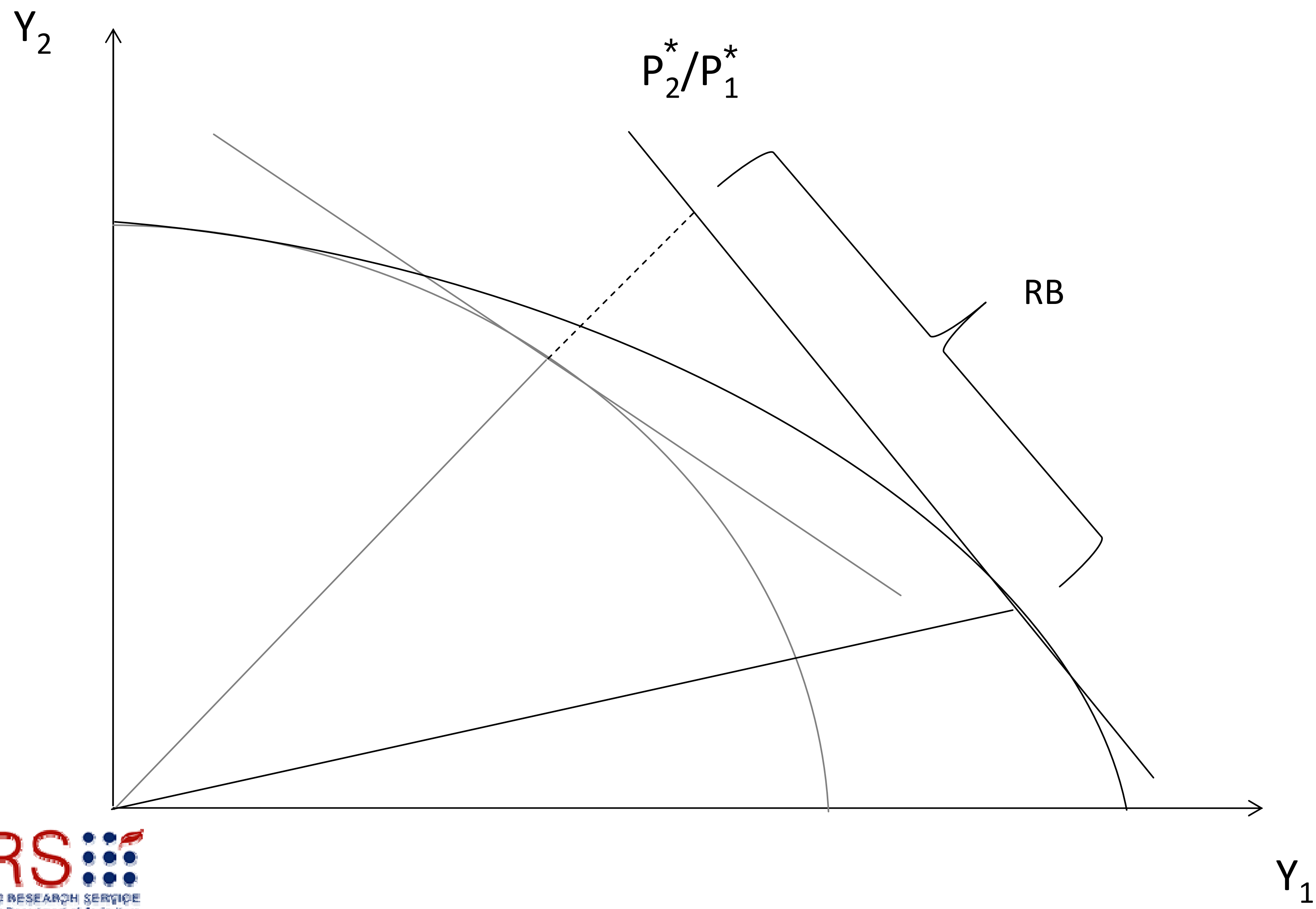
How Did Technology Growth Alter Output Choices & Input Factors?



How Did Technology Growth Alter Output Choices & Input Factors?



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Technical Change Bias:

Input Bias	RB_k
Capital	0.08%
Intermediates	0.70%
Labor	-0.55%
Output Bias	RB_i
Annuals	0.35%
Perennials	-0.87%
Livestock	-0.37%

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What Has Been the Total Factor Productivity Growth?

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

'Anti-Agriculture' Period, 1985-1997

Aggregated TCR	*Technical Efficiency Change*	*Total Factor Productivity Growth*
2.14%	0.24%	2.38%

*Mean T.E. level = 96.9%

'Pro-Agriculture' Period, 1998-2005

Aggregated TCR	*Technical Efficiency Change*	*Total Factor Productivity Growth*
2.81%	-0.86%	1.95%

*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

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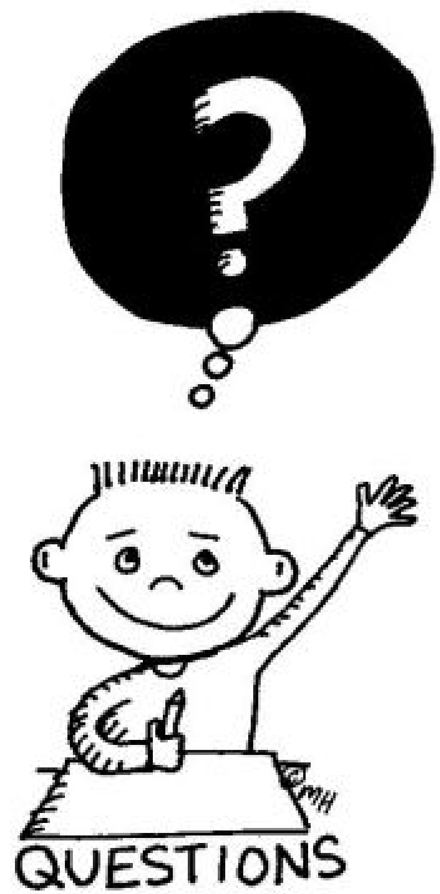
QUESTIONS

What then has been the net average annual impact of improving agricultural incentives between 1985 and 2005?

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

Econometric Approach

- Characterize stochastic frontier as:

$$e^{h(\ln x_{kit}, \ln y_{jit}, t, \beta)} = e^{\left(v_{it} - g(\ln z_{ait}; \Omega)\eta_{it}\right)}.$$

- Specify an exponential form:

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

$$e^{h(\ln x_{kit}, \ln y_{jit}, t, \beta)} = e^{\left(v_{it} - \exp(\ln z_{ait}{}'\Omega)\eta_{it}\right)}.$$

- 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:

$$
\begin{aligned}
-\ln y_{mit} &= h(\ln x_{kit}, \ln y^{*}_{jit}, t, \beta) + g(\ln z_{ait}; \Omega)\eta_{it} - \nu_{it}, \\
&= h(\ln x_{kit}, \ln y^{*}_{jit}, t, \beta) + \exp\left\{\ln z_{ait}{}'\Omega\right\} + \varepsilon_{it},
\end{aligned}
$$

where

$$\varepsilon_{it} = -\nu_{it} + \exp\left\{\ln z_{ait}{}'\Omega\right\}(\eta_{it} - 1).$$

- The variance of my estimable model is

$$Var(-\ln y_{mit}) = \exp\{2\ln z_{ait}{}'\Omega\}\sigma_{\eta}^{2} + \sigma_{\nu}^{2}$$

- Two moments of composed error:

$$
\begin{aligned}
E(\varepsilon_{it}) &= 0, \\
V(\varepsilon_{it}) &= \sigma_{\nu}^{2} + \exp\left\{2\ln z_{ait}{}'\Omega\right\}\sigma_{\eta}^{2},
\end{aligned}
$$

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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:

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

$$\lambda_{it} = \frac{\sigma_{u,it}}{\sigma_v} = \frac{\sqrt{g(\ln z_{ait};\Omega)}}{\sigma_v}.$$

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AARD Funding

	1981-1985	1991-1995	2001-2003
Ag.GDP (billions)	60.3	88.6	110.3
Ag. Research expenditures % of Ag.GDP	0.3 %	0.3 %	0.2 %
Ag. Research spending per farm	10.7	10.6	9.4

- Fuglie and Piggott (2006)

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