Misallocation and Productivity in Agriculture

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Motivation

- Large differences in GDP per capita between rich and poor countries mostly explained by differences in labor productivity and in particular total factor productivity

- Resource (mis)allocation across heterogeneous production units a key determinant of aggregate productivity

- Key questions:
  - What specific policies/institutions/frictions cause misallocation?
  - How do they affect productivity at the industry level?

- Focus:
  - Industry → Agriculture
  - Specific Policy/Friction → Land reforms and imperfect land markets
Why agriculture?
Agricultural Labor Productivity

- Poor countries are particularly unproductive in agriculture ...

Source: Restuccia, Yang, and Zhu (2008, JME), PWT, FAO
Agricultural Employment Shares

- ... and poor countries devote most of their labor to agriculture.

![Pie charts showing agricultural and non-agricultural employment shares for poor and rich countries.]

Source: Restuccia, Yang, Zhu (2008, JME), FAO
Motivation

- Understanding labor productivity gap in agriculture is key. Several explanations ...

- Adamopoulos and Restuccia (forthcoming, AER)
  - Integrates literatures on misallocation and agricultural productivity differences
  - Poor countries characterized by institutions, market frictions, and policies creating misallocation in agriculture
  - These features manifest themselves through farm size
  - Can be quantitatively important in thinking about agricultural productivity
Two Specific Applications

(1) “Land Reform and Productivity: A Quantitative Analysis with Micro Data” (with Tasso Adamopoulos)
Land Reforms

- Typically involve redistribution of farm land above a given ceiling from land-rich to land-poor

- Often coupled with a “shutting down” of land sales and/or rental markets

- Prevalent in developing countries in the second half of the 20th century
### Some Land Reforms

<table>
<thead>
<tr>
<th>Country</th>
<th>Change in AFS (%)</th>
<th>Land Reform Period</th>
<th>Ceiling on Land Size (Ha)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bangladesh</td>
<td>-49.1</td>
<td>1984</td>
<td>8</td>
</tr>
<tr>
<td>Ethiopia</td>
<td>-44.1</td>
<td>1975</td>
<td>10</td>
</tr>
<tr>
<td>India</td>
<td>-25.8</td>
<td>by early 1970s</td>
<td>by province: 4-53</td>
</tr>
<tr>
<td>Korea</td>
<td>-21.5</td>
<td>1950</td>
<td>3</td>
</tr>
<tr>
<td>Pakistan</td>
<td>-11.5</td>
<td>1972, 1977</td>
<td>61, 40</td>
</tr>
<tr>
<td>Sri Lanka</td>
<td>-26.2</td>
<td>1972</td>
<td>10-20</td>
</tr>
<tr>
<td>Philippines</td>
<td>-29.6</td>
<td>1988</td>
<td>5</td>
</tr>
</tbody>
</table>

- AFS drops after all these reforms against the tendency for AFS to increase over time
Research Questions

1. What are the effects of land reforms on farm size and agricultural productivity?

2. Through what channels do these effects manifest themselves?
Our Approach

- Focus on a particular land reform (Philippines)
- Use micro data to study the decisions of operators at the farm-level before and after the reform
What We Do

1. Develop an industry model that features a non-degenerate distribution of farms and a technology choice at the farm level.

2. Calibrate the model to pre-reform farm-level data in the Philippines.

3. Use the quantitative model to measure the effects of:
   - land reform alone
   - land reform alongside other changes.
What We Find

1. The land reform reduces productivity by 17% and farm size by 34%, it also reduced the share of landless by 20%

2. These effects due to both misallocation and selection (distortion to occupational and technology choices)

3. How land redistribution takes place is key for magnitude of productivity drop

4. A market-based redistribution yields less than 1/3 of these effects

5. Other changes occurring alongside the reform can mask the effects of the reform
Land Reform in the Philippines

- 1988 land reform in the Philippines: Comprehensive Agrarian Reform Program (CARP)
- imposed ceiling of 5 Ha on all agricultural holdings
- severely restricted transferability of the redistributed farm lands
- targeted 80% of total farm land
- 80% of targeted farmland redistributed by mid-2000s
- Restrictiveness ratio: $\frac{\text{ceiling}}{\text{pre-reform AFS}} = 1.75$
Micro Data - Philippines

   - Complete enumeration of farms
   - No outputs or inputs other than land, labor

2. Philippines Cash Cropping Project (1984, 2003), IFPRI
   - Survey data: Island of Mindanao, Bukidnon province
   - Can calculate productivity at the farm-level
Average Farm Size - Census Data

- pre-reform (1981) AFS = 2.85 Ha
- post-reform (2002) AFS = 2.01 Ha
- AFS dropped by 29.6%
Changes in Size Distribution of Farms - Census Data

<table>
<thead>
<tr>
<th>Farm Size (Ha)</th>
<th>1981 Census</th>
<th>2002 Census</th>
</tr>
</thead>
<tbody>
<tr>
<td>0−1</td>
<td>0.40</td>
<td>0.30</td>
</tr>
<tr>
<td>1−2</td>
<td>0.25</td>
<td>0.35</td>
</tr>
<tr>
<td>2−5</td>
<td>0.20</td>
<td>0.30</td>
</tr>
<tr>
<td>5−10</td>
<td>0.15</td>
<td>0.20</td>
</tr>
<tr>
<td>10+</td>
<td>0.05</td>
<td>0.10</td>
</tr>
</tbody>
</table>

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Misallocation and Productivity in Ag.

2014 17 / 51
Agricultural Labor Productivity - Industry Accounts

Real VA Per Worker in Agriculture

Land Reform, 1988

% change 1990-1993: -11.6%
Micro Data - IFPRI

- Household survey data
- 448 households interviewed in 4 round over 1984-85
- Original households and their children interviewed again in 5 rounds over 2003-04
- Precise and detailed measurement of inputs and outputs at the parcel and farm level
- Food crops: corn, rice; Cash crops: sugarcane (mainly), coconut, coffee, rubber
## Size and Productivity By Crop - Panel

<table>
<thead>
<tr>
<th></th>
<th>1984-85</th>
<th>2003-04</th>
<th>% change</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>All Farms</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Average Farm Size</td>
<td>3.7</td>
<td>3.1</td>
<td>-17.6</td>
</tr>
<tr>
<td>Value Added Per Work Day</td>
<td>257.5</td>
<td>372.7</td>
<td>44.7</td>
</tr>
<tr>
<td><strong>Cash Crop Farms</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Average Farm Size</td>
<td>4.6</td>
<td>3.7</td>
<td>-19.8</td>
</tr>
<tr>
<td>Value Added Per Work Day</td>
<td>298.2</td>
<td>386.1</td>
<td>29.5</td>
</tr>
<tr>
<td><strong>Food Crop Farms</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Average Farm Size</td>
<td>2.1</td>
<td>1.3</td>
<td>-39.0</td>
</tr>
<tr>
<td>Value Added Per Work Day</td>
<td>101.2</td>
<td>201.0</td>
<td>98.7</td>
</tr>
</tbody>
</table>

- In 1984-85 cash crop farms are larger and more productive.
## Exiting and Continuing Farms

### Average Farm Size and Productivity

<table>
<thead>
<tr>
<th></th>
<th>Exiting Farms</th>
<th>Continuing Farms</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>All</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Farm Size</td>
<td>2.3</td>
<td>3.5</td>
</tr>
<tr>
<td>Productivity</td>
<td>242.4</td>
<td>254.3</td>
</tr>
<tr>
<td><strong>Top 10%</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Farm Size</td>
<td>5.2</td>
<td>6.7</td>
</tr>
<tr>
<td>Productivity</td>
<td>529.5</td>
<td>556.7</td>
</tr>
</tbody>
</table>

- Productivity drop not explained by most productive farmers leaving agriculture after reform

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Misallocation and Productivity in Ag. 2014 21 / 51
Economic Environment

- Industry model of agriculture - production side
- Build from Lucas (1978) span-of-control model of firm size \(\Rightarrow\) non-degenerate distribution of farms
- In addition, operators face a cropping technology choice (cash vs. food crop)
Production unit is a farm, that requires the input of an operator (farmer) with managerial skills $s$, land input ($\ell$), and hired labor ($n$).

There are two types of crops, cash crops ($c$) and food crops ($f$).

Farmer of ability $s$ produces crop $i \in \{c, f\}$ according to the decreasing returns to scale technology,

$$y_i = (A\kappa_is)^{1-\gamma}(\ell^\alpha n^{1-\alpha})^\gamma$$

- $A =$ economy-wide productivity (TFP)
- $\kappa_i =$ crop-specific productivity parameter
- $\gamma =$ span-of-control parameter
Farmer Problem

- Farmer of ability $s$, operating technology $i \in \{c, f\}$ maximizes profits given prices $(w, q, p_i)$,

$$\max_{\ell, n} \{ p_i y_i - wn - ql - p_i C_i \}$$

- $C_i$ = crop-specific fixed cost of operation
- $p_i$ = price of crop $i \in \{c, f\}$ (fixed)
Farmer Problem

- Optimal scale of farm operation determined by farmer ability,
  \[ l_i(s) = \left( \frac{\alpha}{q} \right)^{\frac{1 - \gamma(1 - \alpha)}{1 - \gamma}} \left( \frac{1 - \alpha}{w} \right)^{\frac{\gamma(1 - \alpha)}{1 - \gamma}} (\gamma p_i)^{\frac{1}{1 - \gamma}} A\kappa_i s, \]

- Optimal land and hired labor demands \([l(s), n(s)]\) imply,
  \[ \frac{n(s)}{l(s)} = \frac{(1 - \alpha)}{\alpha} \frac{q}{w}, \]

- Given input demands and output functions profits are,
  \[ \pi_i(s) = (1 - \gamma)p_i y_i(s) - p_i C_i. \]
Farmers are heterogeneous in their managerial ability, $s \sim F(s)$ with support in $S = [s_{min}, s_{max}]$

There are two thresholds that determine the fraction of farmers being hired workers, cash crop farmers, and food crop farmers.

Denote occupational choice by $o_i(s)$, with $o_i(s) = 1$ if $\pi_i \geq \max\{\pi_{-i}(s), w\}$
Suppose that $C_c > C_f$ and $\kappa_c > \kappa_f$.

$s$ is the cutoff for hired workers vs. operators

$$\pi_f(s) = w$$

$\bar{s}$ is the cutoff for food crop vs. cash crop operators

$$\pi_f(\bar{s}) = \pi_c(\bar{s})$$
Illustration
Calibration I

- **Strategy:** Calibrate benchmark economy (BE) to pre-reform Philippines

- Distribution of farmer ability $F(s)$ approximated by a log-normal distribution, with mean $\mu$ and variance $\sigma$, chosen to match the distribution of farm sizes from the survey data.
Calibration II

- Normalize the relative price of cash to food crops $p_c/p_f$ to 1
- Normalize $A$ and $\kappa_f$ to 1
- Set span-of-control parameter to $\gamma = 0.7$
- Choose $\alpha = 0.3$ to match a land income share of 0.2
- Aggregate land endowment $L$ chosen to match an average farm size of 3.7 Ha (survey data)
Solve the model for \((C_f, C_c, \kappa_c)\) to match three targets from the 1984-85 survey data:

(a) share of hired labor in total farm labor of 61.1%
(b) share of cash crop operators in total operators of 61.7%
(c) disparity of average output per worker between cash crops and food crops of 2.95
Model vs. 1984-85 Survey Data

Farm-size distribution

<table>
<thead>
<tr>
<th>Farm Size Class in Ha</th>
<th>Fraction of Farms</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt;1</td>
<td>0.05</td>
</tr>
<tr>
<td>1−2</td>
<td>0.1</td>
</tr>
<tr>
<td>2−5</td>
<td>0.15</td>
</tr>
<tr>
<td>5−7</td>
<td>0.2</td>
</tr>
<tr>
<td>7−10</td>
<td>0.25</td>
</tr>
<tr>
<td>10−15</td>
<td>0.3</td>
</tr>
<tr>
<td>15+</td>
<td>0.35</td>
</tr>
</tbody>
</table>

Share of land by size

<table>
<thead>
<tr>
<th>Farm Size Class in Ha</th>
<th>Fraction of Land</th>
</tr>
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<tbody>
<tr>
<td>&lt;1</td>
<td>0.05</td>
</tr>
<tr>
<td>1−2</td>
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</table>
Land Reform I

- Model land reform as a government-mandated redistribution program.

- Farmland in excess of the effective ceiling is redistributed to the landless and smallholders.

- Land market is not operative.

- Redistributed land constitutes an endowment for each recipient (cannot be adjusted).
Land Reform II

Implement government-mandated redistribution using four parameters:

- legislated land ceiling \( l_{max} \).
- probability \( \theta \) that farmers above the ceiling retain their previous farm size (enforcement).
- fraction of landless \( \beta \) that receive land
- fraction \( \psi \) of smallholders that receive land

These parameters fully determine the post-reform distribution of land (farms).
Philippine Land Reform

Experiment

- take the benchmark economy calibrated to (pre-reform) Philippines
- consider the above government-mandated land redistribution
  - feed in ceiling of 5 Ha
  - pick $\theta$ to roughly match farm distribution $> 5$ ha
  - pick $(\beta, \psi)$ to roughly match farm distribution for bins $0 - 1$ ha, $2 - 3$ ha.
Land Reform vs. 2003-04 Survey Data

**Farm-size distribution**

- **Fraction of Farms**
  - <1
  - 1−2
  - 2−5
  - 5−7
  - 7−10
  - 10−15
  - 15+

- **Farm Size Class in Ha**
  - <1
  - 1−2
  - 2−5
  - 5−7
  - 7−10
  - 10−15
  - 15+

- **Govt-mandated reform**
- **2003 Survey Data**

**Share of land by size**

- **Fraction of Land**
  - <1
  - 1−2
  - 2−5
  - 5−7
  - 7−10
  - 10−15
  - 15+

- **Farm Size Class in Ha**
  - <1
  - 1−2
  - 2−5
  - 5−7
  - 7−10
  - 10−15
  - 15+

- **Govt-mandated reform**
- **2003 Survey Data**

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Misallocation and Productivity in Ag.

2014 37 / 51
### Aggregate Effects of Land Reform

<table>
<thead>
<tr>
<th></th>
<th>Government-mandated Land Redistribution</th>
<th>Market-based Land Redistribution</th>
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</tr>
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<tbody>
<tr>
<td>Farm Size</td>
<td>-34.2</td>
<td>-9.3</td>
<td>-29.6</td>
</tr>
<tr>
<td>Productivity</td>
<td>-17.0</td>
<td>-5.0</td>
<td>-11.6</td>
</tr>
<tr>
<td>Landless (%)</td>
<td>-20.0</td>
<td>-4.0</td>
<td>-19.0</td>
</tr>
</tbody>
</table>
Degree of Enforcement of Reform

<table>
<thead>
<tr>
<th></th>
<th>Enforcement</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>$\theta = 0.8$</td>
</tr>
<tr>
<td>Average Farm Size</td>
<td>-34.2</td>
</tr>
<tr>
<td>Ag. Labor Productivity</td>
<td>-17.0</td>
</tr>
</tbody>
</table>

- Enforcement of reform ceiling is quantitatively important for the magnitude of size and productivity drop
Importance of Vehicle of Redistribution

- Land market “shut-down” key for magnitude of productivity decline
- Consider market-based redistribution
  - only restriction is the ceiling
  - land market is allowed to work
- Ceiling with land market reallocation compresses the farm and land distribution creating smaller size and productivity effects
## Aggregate Effects of Land Reform

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<td>Productivity</td>
<td>-17.0</td>
<td>-5.0</td>
<td>-11.6</td>
</tr>
<tr>
<td>Landless (%)</td>
<td>-20.0</td>
<td>-4.0</td>
<td>-19.0</td>
</tr>
</tbody>
</table>

- Market-based redistribution generates less than 1/3 of the effects
Market-based Redistribution vs. 2003-04 Survey Data

Farm-size distribution

Land Share by Farm Size

- Does not capture the reality of reform in the Philippines
## Productivity Decomposition

<table>
<thead>
<tr>
<th></th>
<th>Government-mandated Land Redistribution</th>
<th>Market-based Land Redistribution</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total Effect</td>
<td>-17.0</td>
<td>-5.0</td>
</tr>
<tr>
<td>Misallocation Effect</td>
<td>-1.1</td>
<td>-3.0</td>
</tr>
<tr>
<td>Selection Effect</td>
<td>-15.9</td>
<td>-2.0</td>
</tr>
</tbody>
</table>

- Misallocation effect roughly similar, but selection effect much larger under government-mandated redistribution
Two Specific Applications

(2) “Land Misallocation and Productivity” (with Raul Santeulalia-Llopis)
Land Misallocation in Malawi

- Large, representative micro data with excruciating detail on agricultural production and productivity

- Land markets largely undeveloped in Malawi
  - more than 70% of land is inherited
  - almost none of the land comes with a title
  - almost no rentals

- Land fairly evenly distributed across households at very low operational scales
  - more than 70% of households operate less than 2 acres of land
Distribution of Farm Productivity in Malawi
Dispersion of Farm and Plant Productivity

<table>
<thead>
<tr>
<th>Statistic</th>
<th>Malawi 2010</th>
<th>USA 1977</th>
<th>China 1998</th>
<th>India 1987</th>
</tr>
</thead>
<tbody>
<tr>
<td>SD</td>
<td>0.86</td>
<td>0.85</td>
<td>1.06</td>
<td>1.16</td>
</tr>
<tr>
<td>75-25</td>
<td>1.08</td>
<td>1.22</td>
<td>1.41</td>
<td>11.55</td>
</tr>
<tr>
<td>90-10</td>
<td>2.14</td>
<td>2.22</td>
<td>2.72</td>
<td>2.77</td>
</tr>
<tr>
<td>N</td>
<td>10,000</td>
<td>164,971</td>
<td>95,980</td>
<td>31,602</td>
</tr>
</tbody>
</table>
Capital and land size not related to productivity!
Land productivity increases with farm TFP, indicative of misallocation!
Q: What would the agricultural productivity increase be of land reallocation across existing farmers to maximize output?

The reallocation involves reallocating land to equalize yields (land productivity) across farmers.

A: Agricultural productivity would increase by a factor of 4-fold!

The increase would be much larger if the number of farms is adjusted via general equilibrium effects (average farm size increase) and if there is selection into the farm exit.

Efficiency of land markets key.
Final Remarks

- Measurable land reform policies generate land misallocation
- Redistributive land policies affect operational farm scales through limited or not well functioning land markets
- Implied land misallocation generates substantial negative effects on agricultural productivity
  - Land reform in Philippines generates a 17% drop in productivity, a very large effect for a single policy
  - Eliminating land misallocation in Malawi among existing farmers can generate a 4-fold increase in productivity
- These result emphasize the importance of developing efficient land markets