The Role of Land Market in Achieving the Scale for Adaptation to Climate Change: Evidence from Bangladesh

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Can Farmers Adapt by Reallocating Farmlands?

- Climate change induced shocks are affecting agricultural productivity: e.g., extreme temperature, drought, salinity intrusion
- Farmers in developing countries are heavily exposed to these shocks
- Ricardian view: effects can be mitigated if farmers reallocate lands according to evolving comparative advantage (Costinot et al., 2016)
  - Drought: cotton to beans, rice to fruit
  - Salinity intrusion: rice to aquaculture
- In practice, rate of reallocation might be slow in developing countries: frictions
Frictions in Reallocation Process

- High fragmentation of farmlands in developing countries
- Switching to farming with higher economies of scale needs consolidation
  - Example: rice to fruit, rice to aquaculture
- Potential barriers to farm size consolidation:
  - Sales: cultural barrier in selling lands inherited across generations
  - Rental: weak de-facto property rights, poor contract enforcement
- High fragmentation → multiple transactions for consolidation → hold up problems
To what extent farmers can switch to farming techniques with higher scales in response to climate shocks?

What mechanisms enable smallholders to achieve the scale required for reallocation? Does land market play any role in it?

What frictions limit the extent of land reallocation?
Overview of This Paper

Context:
- Salinity intrusion in coastal farmlands of Bangladesh
- Adaptation by reallocating farmlands from crop farming to aquaculture
- Minimum scale in aquaculture: needs consolidation for adaptation

Findings:
- Salinity $> 12 \text{ dS/m}$: land allocated to aquaculture doubles, 17% increase in farm size concentration
- No evidence of ownership consolidation, farm size consolidation through rental market of land
- Evidence on friction: lower religious diversity decreases land reallocation by half
- Back of the envelope estimation: annual loss of approx. $450 in farm income per household
Salinity Intrusion in Bangladesh

- Massive increase in dry season soil salinity

Impact on resilient varieties of rice:
- BRRI Rice-47: No impact on productivity up to 8 dS/m, declines by 43% at 12 dS/m (Radanielson et al., 2018)
- New resilient varieties: BRRI Rice-99 and BINA Rice-10 are resilient up to 12 dS/m
Adaptation to Salinity Intrusion

- Strategy: reallocating farmlands to aquaculture in dry season, prevalent in China, India, Indonesia, Vietnam
- Primarily shrimp and crab farming, ideal salinity level 10-20 dS/m

Aquaculture has a minimum scale of about 35 decimals

Median agricultural plot size is 18 decimals → reallocation requires consolidation
Salinity: Survey Data

- Soil salinity data from Soil Resources Development Institute (SRDI) survey 2009
  - 2500 sample points
  - Divides coastal region into five categories: 0 to 4 dS/m, 4.1 to 8 dS/m, 8.1 to 12 dS/m, 12.1 to 16 dS/m, above 16 dS/m
  - 40 percent of the villages have more than 12 dS/m salinity

- Agricultural Census 2008:
  - Full count, household level survey
  - Land use, land ownership, land rented in, land leased out
Key Model Assumptions

- Two crops: productivity of crop 1 (agriculture) declines with salinity, and crop 2 (aquaculture) thrives in salinity.
- Each farm is endowed with $\bar{l}_{i,v}$ farmland and crop specific TFP given by $z_{1,i}$ and $z_{2,i}$.
- $y_{1,i,v} = \frac{z_{1,i}}{S_v} * l_{1,i,v}^{\gamma_1}$, $y_{2,i,v} = z_{2,i,v} * l_{2,i,v}^{\gamma_2}$, where $\gamma_2 > \gamma_1$.
- Farmers can’t sell their endowed lands so that land transactions occur only through rentals.
- Farm specific transaction costs:
  - $\tau_{1,i,v} = \tau_{i,v} =$ transaction costs in the rental market.
  - $\tau_{2,i,v} = \tau_{i,v} + \psi_{i,v}$, where $\psi_{i,v}$ denotes additional costs for consolidation.
- Farmers choose amount of land to rent in and out, and allocation between crop 1 and 2 to maximize profit s.t.
  $$l_{1,i,v} + l_{2,i,v} = \bar{l}_{i,v} + l_{1,i,v}^{in} + l_{2,i,v}^{in} - l_{i,v}^{out}$$
Effect of increased salinity:
- Increase in land allocated to aquaculture, increase in farm size concentration
- The rate of increase decreases in transaction costs
- Rental market: fewer farmers rent in land and conditional on renting each farmer rents higher amount
Identification Strategy

- Challenge: farms with high aquaculture productivity might bring saline water to their field
- Natural variation: tidally active delta vs. mature delta
- Network of tidal channels within tidally active delta & semi-diurnal tides flows through the channels
- Tidal water infiltrates into shallow aquifers, capillary movement from aquifers cause soil salinization
- Increase in salinity at the frontier of tidally active delta
- Fuzzy Spatial RD Design: $1\{Within Tidal Delta\}_v$ as an instrument for $1\{Salinity > 12dS/m\}_v$
- Threat: direct impact through other differences except salinity: e.g., soil nutrients, flooding
Fuzzy RD Specification

\[ Y_{hv} = \gamma \cdot 1\{Salinity > 12dS/m\} + \beta d_v + \phi d_v \cdot 1\{Salinity > 12dS/m\} + \lambda_l + \epsilon_{hv} \]  

- \(Y_{hv}\) is the outcome of interest for household \(h\) in village \(v\)
- \(d_v\): nearest distance to frontier, positive for villages within tidal delta
- \(1\{Salinity > 12dS/m\}_v\): whether the centroid of village \(v\) falls within areas with above 12 dS/m salinity
- \(N_v = 1\{d_v > 0\}\) as an instrument for \(1\{Salinity > 12dS/m\}_v\)
- \(\lambda_l\): longitude-quartile FE (Ito & Zhang, 2020)
- Local linear, triangular kernel, MSE optimal bandwidth following Calonico et al. (2014)
Regression Discontinuity Plot

Distance from tidal delta frontier (km)

P(Salinity > 12 dS/m)
# First Stage Results

<table>
<thead>
<tr>
<th></th>
<th>RD First Stage</th>
<th>IV First Stage</th>
</tr>
</thead>
<tbody>
<tr>
<td>$1{Salinity &gt; 12 \text{ dS/m}}$</td>
<td>0.429***</td>
<td>0.604***</td>
</tr>
<tr>
<td>$1{d_v &gt; 0}$</td>
<td>(0.119)</td>
<td>(0.0399)</td>
</tr>
<tr>
<td>F-Stats</td>
<td>17</td>
<td>228</td>
</tr>
<tr>
<td>Longitude quartile FE</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>District FE</td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td>$N$</td>
<td>146</td>
<td>2505</td>
</tr>
<tr>
<td>Control Mean</td>
<td>0.38</td>
<td>0.38</td>
</tr>
<tr>
<td>BW (km)</td>
<td>6</td>
<td>NA</td>
</tr>
</tbody>
</table>

Standard errors in parentheses are clustered at village level

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

- Between 43 to 60 percentage point increase in probability of high salinity
Placebo Cutoff Test
## Land Reallocation to Aquaculture

<table>
<thead>
<tr>
<th></th>
<th>Amount of Land in Aquaculture (decimals)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Fuzzy RD</td>
</tr>
<tr>
<td></td>
<td>(1)</td>
</tr>
<tr>
<td>$1{Salinity &gt; 12 \text{ dS/m}}$</td>
<td>50.68**</td>
</tr>
<tr>
<td></td>
<td>(20.57)</td>
</tr>
<tr>
<td>Longitude quartile FE</td>
<td>Yes</td>
</tr>
<tr>
<td>District FE</td>
<td></td>
</tr>
<tr>
<td>Farm Controls</td>
<td>No</td>
</tr>
<tr>
<td>Control Mean</td>
<td>19</td>
</tr>
<tr>
<td>$N$</td>
<td>113146</td>
</tr>
<tr>
<td>BW (km)</td>
<td>6</td>
</tr>
</tbody>
</table>

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- Amount of land allocated to aquaculture more than doubles
- Robust to placebo outcomes, placebo cutoff, and different bandwidth choices
Robustness to Exclusion Threat

- Concern: tidally active delta have direct impact through other permanent differences except salinity: e.g., soil nutrients, flooding

### Results

<table>
<thead>
<tr>
<th></th>
<th>Rabi Season Crops</th>
<th>Rabi Season Rice Tolerant</th>
<th>Rabi Season Rice Sensitive</th>
<th>Kharif Season Rice</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Rice (1)</td>
<td>Wheat (2)</td>
<td>Rice (3)</td>
<td>Rice (4)</td>
</tr>
<tr>
<td>1{Salinity &gt; 12 dS/m}</td>
<td>-34.25***</td>
<td>-0.852***</td>
<td>-6.373***</td>
<td>-27.88***</td>
</tr>
<tr>
<td></td>
<td>(3.158)</td>
<td>(0.142)</td>
<td>(1.073)</td>
<td>(3.596)</td>
</tr>
<tr>
<td>Standard errors in parentheses are clustered at village level</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

- Reallocated land from Rabi season crop farming
- Impact is greater on the use of salinity sensitive rice varieties
- No effect on Kharif season rice farming
Effect of Salinity on Farm Size Consolidation: Results

<table>
<thead>
<tr>
<th></th>
<th>Gini Index</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Farm Size Land Ownership</td>
</tr>
<tr>
<td></td>
<td>(1)</td>
</tr>
<tr>
<td></td>
<td>(2)</td>
</tr>
<tr>
<td>$1{Salinity &gt; 12 \text{ dS/m}}$</td>
<td>0.114***</td>
</tr>
<tr>
<td></td>
<td>(0.0155)</td>
</tr>
<tr>
<td>District FE</td>
<td>Yes</td>
</tr>
<tr>
<td>Control Mean</td>
<td>0.67</td>
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<tr>
<td>$N$</td>
<td>2505</td>
</tr>
</tbody>
</table>

Standard errors in parentheses are clustered at village level

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

- 17% increase in gini index of farm size
- No evidence of effect on land ownership consolidation
- Potential mechanism: consolidation through land rentals
# Consolidation through Rental Market

<table>
<thead>
<tr>
<th>1{Land Rented in &gt; 0}</th>
<th>Amount rented in</th>
<th>Full Sample</th>
<th>Land rented in &gt; 0</th>
</tr>
</thead>
<tbody>
<tr>
<td>1{Salinity &gt; 12 dS/m}</td>
<td>(1)</td>
<td>(2)</td>
<td>(3)</td>
</tr>
<tr>
<td></td>
<td>-0.216***</td>
<td>-0.568</td>
<td>50.56**</td>
</tr>
<tr>
<td></td>
<td>(0.0460)</td>
<td>(6.620)</td>
<td>(20.10)</td>
</tr>
<tr>
<td>District FE</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Farm Controls</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>N</td>
<td>1166498</td>
<td>1166498</td>
<td>373006</td>
</tr>
<tr>
<td>Control Mean</td>
<td>0.35</td>
<td>20.27</td>
<td>60.23</td>
</tr>
</tbody>
</table>

Standard errors in parentheses are clustered at village level

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

- 61 % decrease in the number of households who rent-in land
- Conditional on renting, amount of land rented-in increases by 83%
- Robustness: no evidence of differential rental activities for housing
Friction: Rental Contract Enforcement between Religious Groups

- Renters make large fixed investment → need contract enforcement
- Enforcement through court is generally infeasible
- Settlement of disputes by local leaders: ward councilors and chairperson of union council
- Two major religious groups: Muslims & Hindus
- Fixed location of land parcels → rental contracts between religious groups are required
- Local leaders’ potential incentive: winning elected offices
  - higher diversity → needs votes from both groups → lower discrimination
  - lower diversity → might discriminate in favor the dominant religion
Religious diversity and adaptation

- Effect of lower religious diversity is ambiguous:
  - Poorer contract enforcement → minority group less likely to rent out → lower adaptation
  - Dominant group might appropriate lands from minorities → more adaptation

- Religious Diversity Index of village \( v = (1 - (X_v^2 + Y_v^2)) \times 100 \)

- Current religious distribution is endogenous: use diversity index of 1961 as an instrument

- Threat: direct effect of diversity through other channels, e.g., institution and public good provision
## Impact of religious diversity on land reallocation

<table>
<thead>
<tr>
<th></th>
<th>Amount of Land in Aquaculture (decimals)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>(1)</td>
</tr>
<tr>
<td>1{\text{Salinity} &gt; 12 \text{dS/m}}</td>
<td>23.64**</td>
</tr>
<tr>
<td></td>
<td>(9.308)</td>
</tr>
<tr>
<td>1{\text{Above Median Diversity}}</td>
<td>-3.323</td>
</tr>
<tr>
<td></td>
<td>(6.314)</td>
</tr>
<tr>
<td>1{\text{Salinity} &gt; 12 \text{dS/m}}</td>
<td>22.62**</td>
</tr>
<tr>
<td></td>
<td>(10.60)</td>
</tr>
<tr>
<td>1{\text{Above Median Diversity in 1961}}</td>
<td>-2.652</td>
</tr>
<tr>
<td></td>
<td>(14.17)</td>
</tr>
<tr>
<td>1{\text{Salinity} &gt; 12 \text{dS/m}}</td>
<td>28.76**</td>
</tr>
<tr>
<td></td>
<td>(10.76)</td>
</tr>
</tbody>
</table>

N 1166439 1166498

Cluster Village Sub-district

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

- Higher religious diversity almost doubles the extent of adaptation
- Robustness: no evidence of direct effect on use of tap water and sanitary toilets, no effect of salinity on religious composition
- Back of the envelope estimation: annual loss of approx. $450 in farm income per household, 35% of mean annual income
Conclusion

- Costinot et al. (2016) provides optimism for climate change adaptation
- Frictions in developing countries limit the process of land reallocation
- Implications: can potentially cause divergence between rich and poor countries
- A research agenda: identifying specific frictions in adaptation and generate evidence base on scalable solutions
Farm Size Comparison

Average farm size, 2000

- United States: 178.4 ha
- United Kingdom: 70.9 ha
- France: 45 ha
- Austria: 34.1 ha
- Netherlands: 22.1 ha
- India: 1.3 ha
- Ethiopia: 1 ha
- Vietnam: 0.7 ha
- Bangladesh: 0.3 ha

Source: Lowder et al. (2016). The number, size, and distribution of farms, smallholder farms, and family farms worldwide. <i>World Development</i>. OurWorldInData.org/farm-size • CC BY
Farm Size vs. GDP

Average farm size vs. GDP per capita, 2000

Source: Lowder et al. (2016), Data compiled from multiple sources by World Bank
Note: GDP per capita is measured in international-$, and corrects for inflation and cross-country price differences.
Minimum Scale in Aquaculture

![Graph showing the relationship between profit per decimal and plot size in decimal. The graph indicates a positive trend where profit increases with increasing plot size.]
Tidally Active Delta

Source: Islam and Gnauck (2008)