Agricultural technology adoption and development: Lessons learned from field experiments

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Randomized control trials in Orissa (seeds) and Senegal (marketing)

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The issue: A widening yield gap

Address here the debate on how to reduce the large and widening yield gap in SSA and SA rain-fed agriculture.

Growing yield gaps for SSA and (parts of) SA suggest a low-level equilibrium trap for technology adoption.
• Observe the limitations to the current **supply-side** approach to technology adoption that starts from existing (presumably adoptable) technologies and seeks ways of removing constraints to adoption.

• Propose instead a **demand-driven** approach that seeks to offer technologies demanded by farmers, customized to their heterogeneous circumstances.

• We proceed in **ten steps**, followed by a **conclusion** about implementation.
Step 1: Agriculture has a key role to play for development, yet has failed to deliver in many countries

- **Role of agriculture** for growth (WDR 2008) and for poverty reduction (SDG1):
  - WDR: agriculture and linked sectors key for **growth** in the “agriculture-dependent” countries
  - SDG1: most of the world **poor** are in SSA & SA, rural, depend on agriculture directly or indirectly

- **Technology adoption** is key for agriculture to fulfill these development functions due to rural population growth and land constraint

- Yet, there is a **growing yield gap** for these regions, showing that agriculture is failing to increase **land productivity** to support growth

- **Labor productivity** in smallholder farming is also low and failing to increase to support rising farm incomes
Step 2. Why are rural households poor? The question of labor calendars

Labor productivity in agriculture a key determinant of income for smallholder farmers and wage workers

Large Non-Ag/Ag gaps in labor productivity per person per year (blue), but low gaps in labor productivity per hour worked (red) (McCullough 2017)
Labor calendars for rural and urban households in Malawi (LSMS-ISA): rural individuals work less and more seasonally
Conclude

• The LSMS-ISA data for Malawi and Uganda show that rural households have equal hours worked at peak agricultural time (planting), with similar labor productivity, but much lower hours worked at other times.

• Rural poverty is importantly due to high seasonality of rural labor calendars.

• Hence, to reduce poverty, there is a key role for development strategies (agricultural and rural transformations) that increase annual labor productivity by filling and smoothing rural labor calendars.
Step 3: Technology adoption is for more than yields. It is to fill in labor calendars with agriculture and RNFE activities

The function of technology adoption is to support four transformations:

- **A Green Revolution (GR)** to increase the yields of staple foods
- **An Agricultural Transformation (AT)** to diversify farming systems toward high value crops
- **A Rural Transformation (RT)** to diversify rural households’ sources of income toward the rural non-farm economy (RNFE) usually linked to agriculture through forward, backward, and final demand linkages
- **A Structural Transformation (ST)** with labor migration toward urban environments and a decline of the share of agriculture in employment and GDP
A pre-requisite to inclusive transformations is **access to assets** (land, animals, human capital) as in BRAC ultra-poor. The desirable policy sequence is consequently: **Assets/GR/AT/RT/ST**

<table>
<thead>
<tr>
<th>Stages of transformation</th>
<th>Processes</th>
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<tr>
<td>Green Revolution</td>
<td>Adoption/diffusion of HYV seeds, fertilizers for staple crops</td>
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<tr>
<td><strong>Agricultural Transformation</strong></td>
<td>Ag diversification toward high value crops</td>
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<td>Development of value chains and contracting</td>
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<td>Development of labor markets</td>
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<td>Rural Transformation</td>
<td>Mechanization and land concentration</td>
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<td>Development of land markets</td>
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<td>Growth of rural non-farm economy (RNFE)</td>
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<td>Structural Transformation</td>
<td>Rural-urban migration</td>
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<td>Urban-based industrialization and services</td>
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Step 4. Field experiments have proved effective to rigorously study technology adoption

- **Causality** between determinants & adoption, and between adoption & impact is difficult to establish from observational data, yet causality is needed for policy reforms and results-based management

- **Field experiments** (RCTs, lab-in-the-field experiments) have been extensively used to establish these causalities (ATAI-Gates/DfID, BASIS-USAID, SPIA-CGIAR)

- Causality identified by constructing a **counterfactual** to treatment interventions to measure impact by difference

- While field experiments have **limitations** (esp. small, short-term, partial equilibrium, limited external validity), they should be used whenever possible, given the question asked, to **rigorously estimate causal relations**

- A **major revolution** in quantitative policy/program analysis
The theory of change used to analyze technology adoption has typically followed a **Red Ocean business strategy** (Kim and Mauborgne)

- **The Red Ocean strategy** starts from the perspective of the **supply side**: there exist technologies (fertilizers, seeds) that increase yields and are available for adoption but are not being adopted
- It then **works on the demand side**: what are the effective **constraints** to the adoption of available technologies? What can be done to remove these constraints?
- This is the initial **ATAI whitepaper** approach
- **“Red Ocean” name**: Cutthroat competition in promoting adoption of existing technologies turns the ocean bloody red
Alternative theory of change: a Blue Ocean business strategy

- The Blue Ocean strategy starts from the perspective of the demand side:
  - Who are the “extreme non-adopters” (most likely to adopt given their circumstances) and why do they not adopt?
  - What are the technology specifications for which they have a WTP given their particular circumstances

- It then works on the supply side:
  - How to adapt/customize agricultural technology to what they would like to adopt?
  - How to make this particular technology locally available for adoption?
  - How to provide information on this technology to farmers so they can understand it and eventually decide to adopt?

- “Blue ocean” name: all technologies not in existence today, but with effective demand, hence with no competition
Step 6. Literature review of controversy on technology adoption: The Brader-Stoop debate for SSA

<table>
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<tr>
<th>Observation</th>
<th>Lucas Brader: Red strategy IITA Director General</th>
<th>Willem Stoop: Blue strategy Wageningen Univ. agronomist</th>
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<tbody>
<tr>
<td>Positive analysis: reasons for low adoption</td>
<td>Low adoption and low yield gains if adopted</td>
<td>Supply-side: technology is available for adoption. Eventually adopted, but low yield gains due to lack of access to complementary inputs (fertilizers, chemicals) Demand-side: No demand for standardized technologies. Demand is for technologies adapted to local agro-ecological, socio-economic/cultural conditions which have huge heterogeneity</td>
</tr>
<tr>
<td>Normative response: strategy to increase adoption</td>
<td>Supply-side: Increase adoption and yields by removing constraints on access to complementary inputs: trade policies, infrastructure, financial services</td>
<td>Demand-side: Provide technology customized to local conditions. Role of NARS and regional coordination (CORAF). Role of farmer and PO for informal experimentation and participatory learning (Farmer Field Schools)</td>
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Hence, a Red vs. Blue strategy has been present in the technology adoption debate for some time
Step 7. Why a GR is difficult to achieve in SSA/SA: Heterogeneity and the limits to adoption

- **Heterogeneity** in agro-ecological conditions limits adoption to farmers with the necessary **complementary factors** (e.g., soil acidity and organic matter for effective chemical fertilizer use)
- **Complementary factors** typically limit adoption to **some 40%** (say) of the farm population in rain-fed farming
  - Credit vouchers: only 28% able to use (Carter)
  - Index insurance: only 6 to 8% uptake at market price (ATAI)
  - Fertilizer:
    - Only 37% can benefit due to lack of complementary factor: lime for soil acidity in Zambia (Jayne)
    - Only 55% can benefit due to lack of complementary factor: organic fertilizer for soil carbon content in Madagascar (Barrett)
• **Complexity**: Rain-fed agriculture makes **learning** about the production function particularly difficult. Heterogeneous conditions across farmers limit social learning (Tjernström). Short duration time series to understand stochastic events

• **Dynamics**: Climate change makes learning a moving target

• **Limited technological options**: Little hope of raising yield ceiling. Focus on yield gains via dealing with heterogeneity (**customization**) and with extreme events (**resilience** to drought, flood, temperature)

**Proposition**: Success with a GR for rain-fed agriculture beyond the 40% adopters under a **Red Strategy** requires designing a **Blue Strategy** for the 60% non-adopters
Step 8. Red Strategy: A lot of progress made in exploring constraints to adoption of existing technologies using RCTs

Many institutional innovations in support of the $40\%$ adopters:

- **Addressing demand-side constraints**
  - Nudges to behavior to overcome time inconsistency in fertilizer purchase (Duflo et al.)
  - Help farmers notice what matters in available information (Hanna et al.)

- **Addressing contextual constraints**
  - Market development: helped by information (Aker), contracts (Ashraf; Casaburi), trading platforms (McIntosh), competitiveness of traders (Falcao), market transparency (Bernard et al.)
  - Access to credit: customization of microfinance schemes (Field and Pande), limited liability (McIntosh), post-harvest
loans (Burke); credit has been shown to be secondary to risk reduction for adoption (Karlan et al.; Emerick et al.)

- **Access to insurance**: Take-up of index insurance can be increased by better contract design, better data and measurement, better marketing, better delivery (Carter).

**But effective supply-side constraints remain**
- Greater efforts needed at securing the local availability of technology given heterogeneity of technological needs.
- Also need more effective information and diffusion methods (extension services to correspond to learning), optimize entry points for social learning (Magruber et al.), use motivated agents in value chains as sources of information and technology (Emerick et al.).

**Conclusion**: Permanence of supply-side constraints associated with heterogeneity of conditions (complementary factors) suggest that a **Blue Strategy** is needed for the non-adopting 60%
Step 9. Blue Strategy: What has been learned from field experiments?

Blue Strategy case study 1: Demand for resilience to specific risk factors: Sub1 rice for flood tolerance (Emerick et al.)

Resilient technology has yield advantage in bad years (shock-coping effect)

- Observe demand for flood-tolerant Swarna-Sub1 vs. regular Swarna rice in flood-prone plots of Eastern India with no yield penalty in normal years: Blue strategy analogy
- Shock-coping value: results from Randomized Control Trials (RCT) allocating 5kg seed-minikits to randomized farmers in randomized villages
Shock-coping value of flood tolerant rice in farmers’ fields

45% yield advantage after 10 days of submergence
Avoided yield loss of 682kg/ha with 10-15 days submersion
• Risk management value of flood tolerance:
  Down-side risk reduction induces farmers to re-optimize and invest more in all years:
  ○ Cultivate more land, use less traditional but resilient low yield rice varieties, use more fertilizer, adopt more labor-intensive planting methods, hold less precautionary savings, and take more credit
  ○ Achieve higher yields (+283kg/ha) in non-flood years

• Net effect of shock-coping and risk management
  ○ Expected gains in normal years (3 in 4) through behavior (private investment) about equal to avoided losses in bad years (1 in 4) through genetic breeding (public investment)
  ○ Shows a 100% public-private yield multiplier effect
Blue Strategy case study 2: Demand for Precision Agriculture for Development (PAD) (Cole and Kremer)

- PAD offers **individualized advice** on technology adoption based on a farm-level soil health cards and individualized diagnostic of options
- Advice delivered through **text messages**. PAD also offers a hot line for farmers to ask questions and engage in **social learning**
- Results in Kenya show an increase in the use of **fertilizers** (complementary to lime) and in **yields**
- Using an RCT, the gain is shown to be associated with the **customization** of advice

Blue Strategy case study 3: Farmer Field Days, peer entry points, and deliberation (Emerick et al.)

- Farmers prefer to learn from **peer farmer** (most analogous)
- Farmer Field Days with various peer farmer demos allow **deliberation**, increasing adoption
Step 10. Multiple constraints (Red Strategy) and multiple demands (Blue Strategy) imply the need to coordinate for joint action

- Theory of change for technology adoption shows **multiple constraints** and demands that must be jointly addressed
- Analogous to the **Big Push/O’Ring** theory of multiple equilibria, with adoption failure if coordination not achieved
- Creativity in lifting individual constraints (ATAI project) needs to be complemented with **coordination effort**
- Ethiopia’s **Ag Transformation Agency** under Prime Minister to prioritize and coordinate interventions to address bottlenecks and meet demands
- **Paraguay**: ministerial coordination at highest level of state power, and **independent implementation agency** in field

→ Stress the role of governance reforms in implementing a Red-Blue approach to overcome low-level equilibrium trap
Conclusion: Unlocking technology adoption in rain-fed agriculture

- A GR for rain-fed SSA/SA is necessary, but hard to achieve and insufficient per-se to take rural households out of poverty.
- An AT/RT is important to fill in labor calendars, increase the annual productivity of labor, and reduce rural poverty.
- Field experiments, when they can be used, have proved useful to rigorously establish causality between determinants & adoption, and between adoption & impacts. They have been extensively used in the ATAI-BASIS-SPIA projects.
- INSEAD’s Red Ocean-Blue Ocean Strategy offers a useful reversal of the determinants of technology adoption for rain-fed agriculture with a high heterogeneity, proposing a demand-driven approach to the supply of customized technologies (non-adopting 60%) additional to a supply-driven quest for removal of constraints on demand (adopting 40%).
• **Low and partial adoption** in rain-fed agriculture due to the role of **complementary factors** suggests the validity of a Blue Strategy. Precedents in the Red-Blue controversy on technology adoption in Sub-Saharan Africa include the CGIAR’s **Brader-Stoop** debate.

• **Review of evidence** from **Red Strategy** RCTs shows that important progress with **constraint removal** (40% adoption) often ends up facing limitations on the supply side of technology (local availability and information), indicating the importance of a complementary **Blue Strategy** (60% others).

• **Successful examples** of a **Blue Strategy** include (1) the adoption of **Sub1** flood-tolerant rice that precisely targets plots with risk of flooding, with no yield penalty, (2) the **Precision Agriculture for Development** service that customizes technological packages based on soil health cards and the specific circumstances of individual farmers, and (3) the
Farmer Field Days approach to extension that offers various peer-farmer entry points in social networks and options for farmer deliberation for social learning

- The multiplicity of customized technologies and effective constraints that need to be jointly addressed suggests the need for coordination to break away from the current low-level equilibrium trap in which rain-fed farming is located. This raises the issue of local governance and the role of producer organizations in addressing the technology adoption dilemma.

- Implementation of a Blue Strategy requires local adaptive research capacity (NARS, local university), private sector agents in value chains (seed companies, agro-dealers, merchants), active producer organizations for participatory R&D, and effective local and regional governance for coordination.
• **Research** and **use of RCTs** in a **Blue Strategy** requires prior comprehensive multi-disciplinary **diagnostics** to identify demand and WTP for new technological options, and to design these new technological options.

• **In conclusion**, the current review of the role of agriculture for development (growth and poverty reduction) suggests:
  - Pursuing a **Blue Strategy** (demand-driven approach) as an important complement to a **Red Strategy** (supply-driven approach and constraint removal).
  - Pursuing governance reforms to achieve greater **coordination** in implementing these strategies.

End

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References