# The Technology Adoption Puzzle: What Can We Learn From Field Experiments?

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## 1. In Praise of John Kenneth Galbraith

Based on research done with Elisabeth Sadoulet, Kyle Emerick, and Manzoor Dar and the broader BMGF/DFID-supported J-PAL-CEGA Agricultural Technology Adoption Initiative

## 2. This Lecture: Observation, Objective, and Thesis

**Observation**: Green Revolution (HYV seeds and fertilizers) occurred in irrigated areas of the world, but less so in (good potential, risky) rainfed areas (Eastern India, SSA). In the latter, low fertilizer use reveals low adoption of HYV seeds.

- **Objective**: Use field experiments to help **explain** the continuing **puzzle of low adoption** of technological innovations by smallholder farmers in rainfed areas where agriculture is under-performing relative to potential
- **Thesis**: **Adoption puzzle** explained importantly by a pervasive **deficit in effective supply of technology** for smallholder farmers in rainfed areas
- **Effective supply** defined as: existence + information + local availability

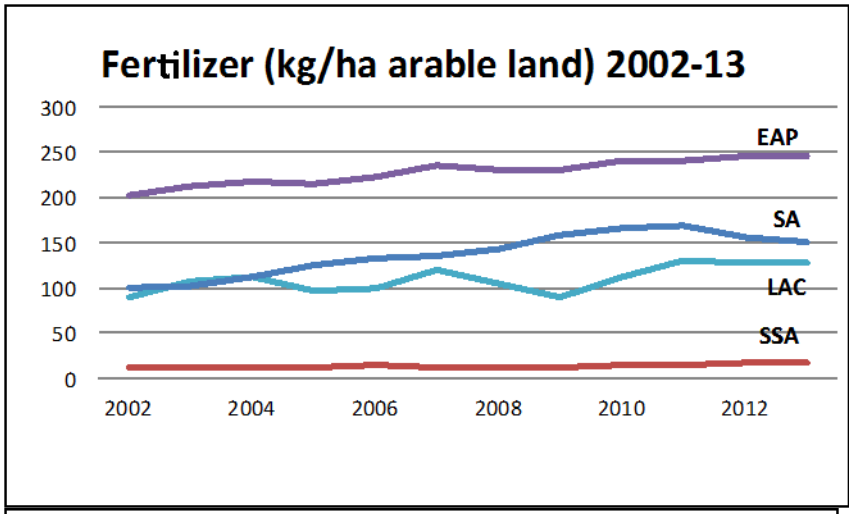
# 3. Facts About Missing Technological Revolutions

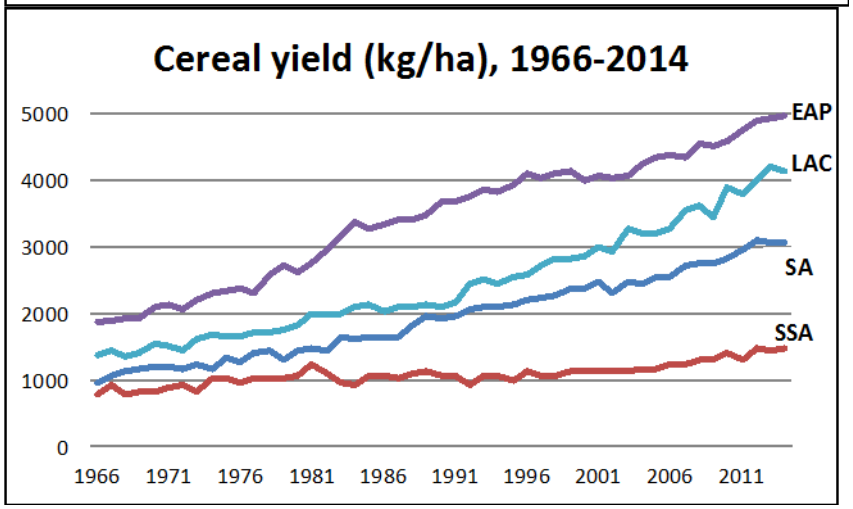
- **What we know:** Agricultural productivity growth essential for the structural transformation, industrial development, and welfare of low income countries (WB-WDR)
  - **History: Agricultural Revolution** (technology and institutions) as a pre-condition to **Industrial Revolution**: England and Western Experience (Bairoch)
  - **Growth theory**: Happens through the production of a food surplus (Lele-Mellor), the release of labor (Jorgenson), the contribution of a financial surplus (Kuznets), and the creation of effective demand for industrial non-tradables (Mellor; Adelman) all of which require **technological change** in agriculture (growth models else than Lewis surplus labor)

- **Growth empirics**:
  - In **all developing countries**, 2/3 of agricultural growth is explained by **productivity** growth and 1/3 by **factor** deepening (Evenson and Fuglie)
  - In **Brazil**, **technological change** in soybeans contributed to industrialization through release of labor and transfer of a financial surplus (Bustos et al.)
- **Welfare**:
  - **Productivity growth** in agriculture necessary for **income gains** by a majority of the **rural poor,** especially with low labor absorption in industry (premature des-industrialization, Rodrik)

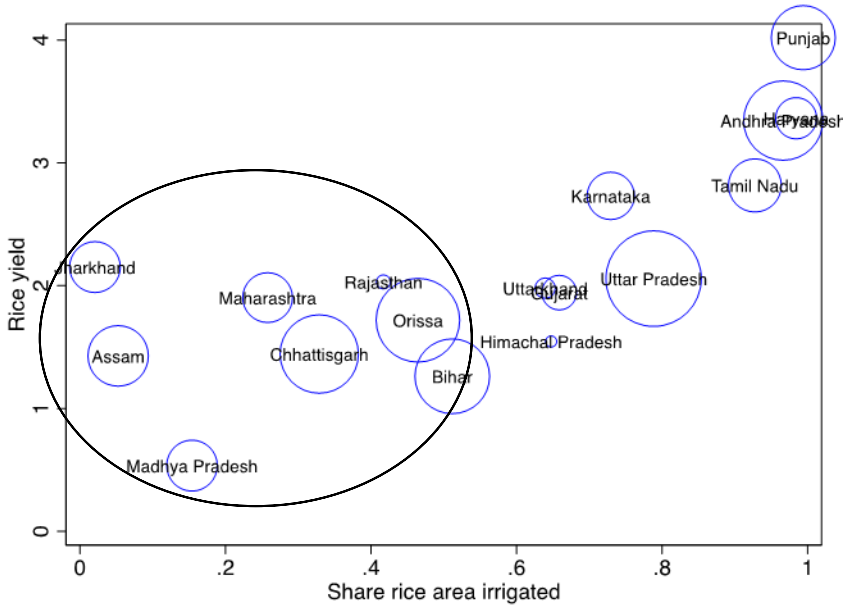
- **Empirical evidence**:

# Low use of fertilizers in SSA and low yields

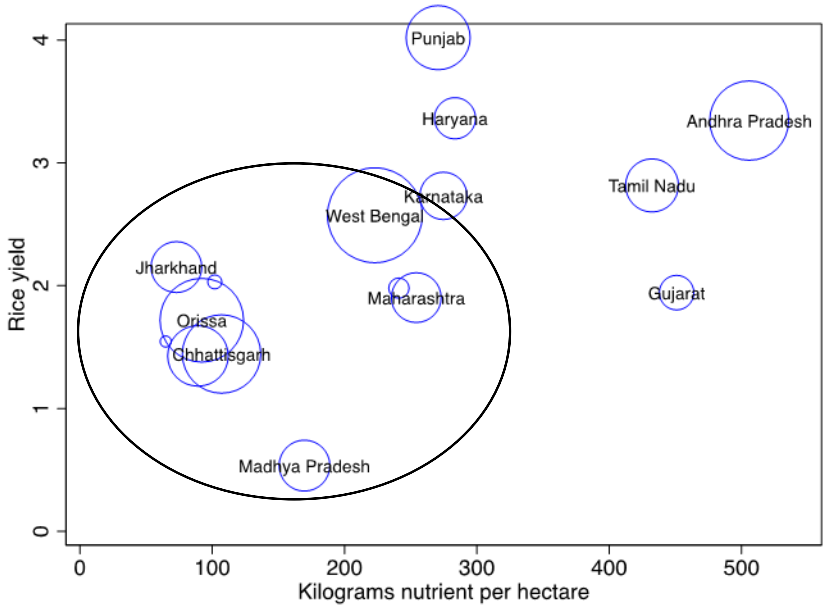


# Indian states: Irrigation, fertilizer use, yields, and rice area (bubble size)



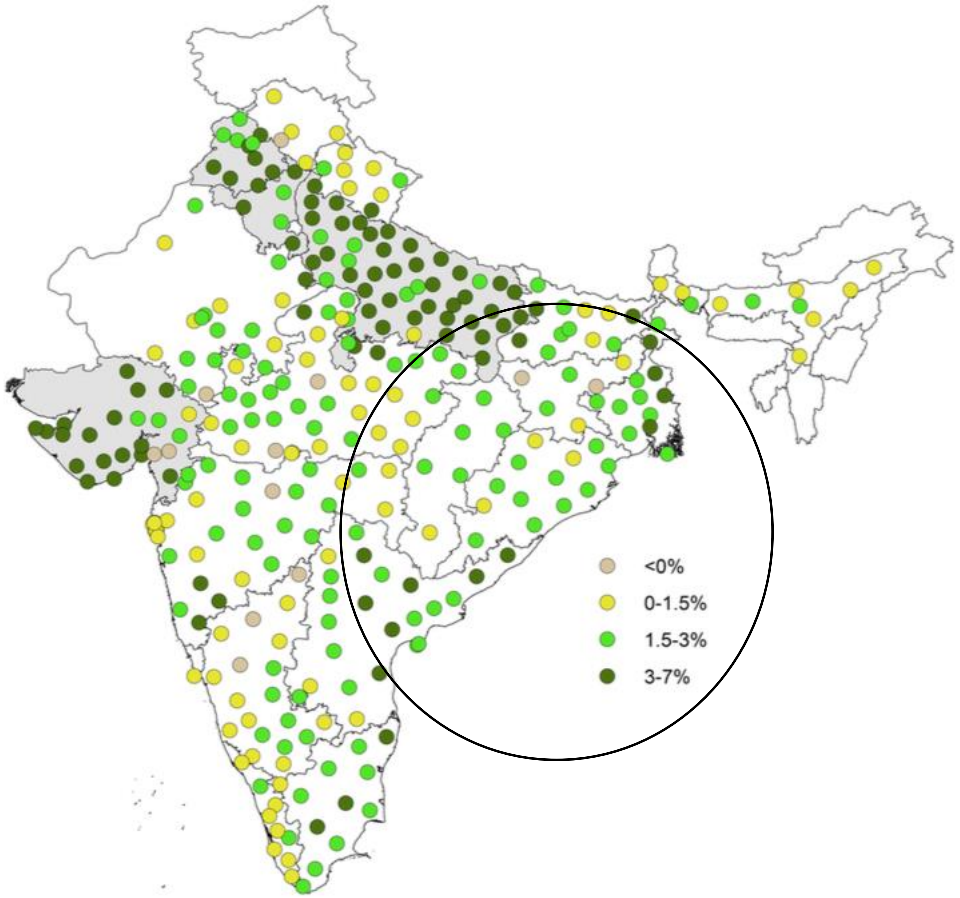

Irrigation




Fertilizer

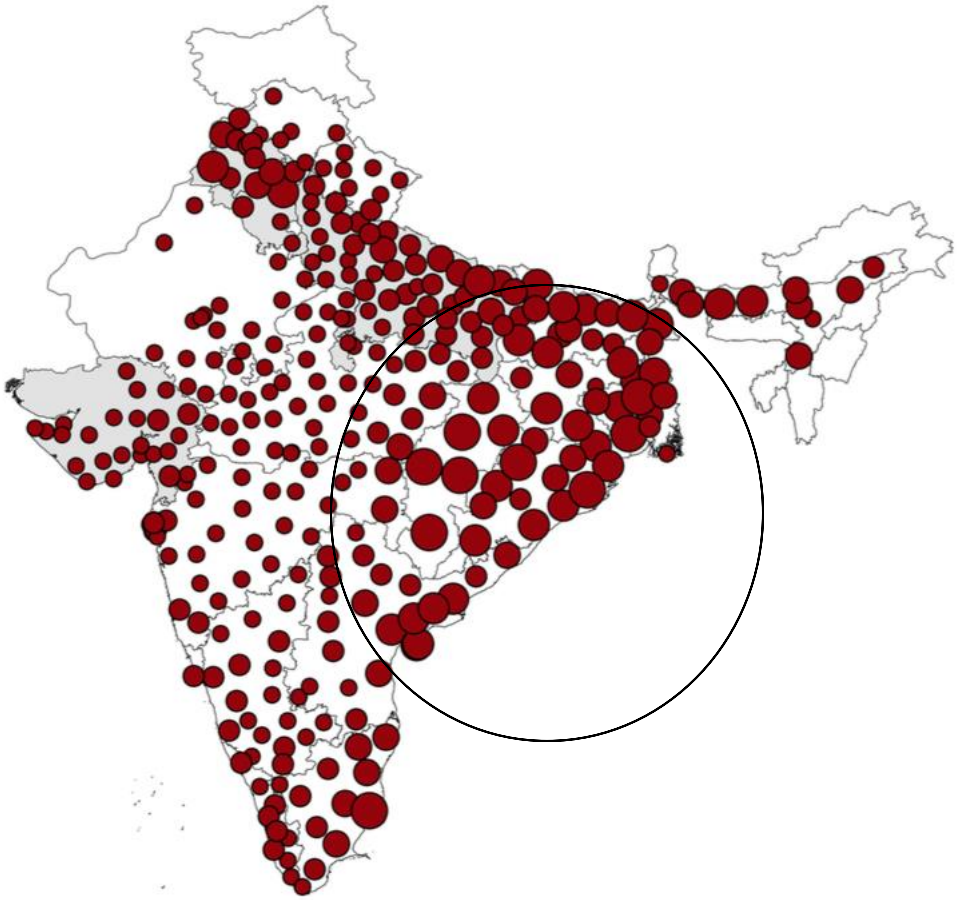
Rainfed states (circled): Both low fertilizer use and low yields

# Lack of fertilizer use results in low yield growth




Color of dot: Growth rate in yield, 1966-2007 (ICRISAT)

# Even though rice is very important in these regions

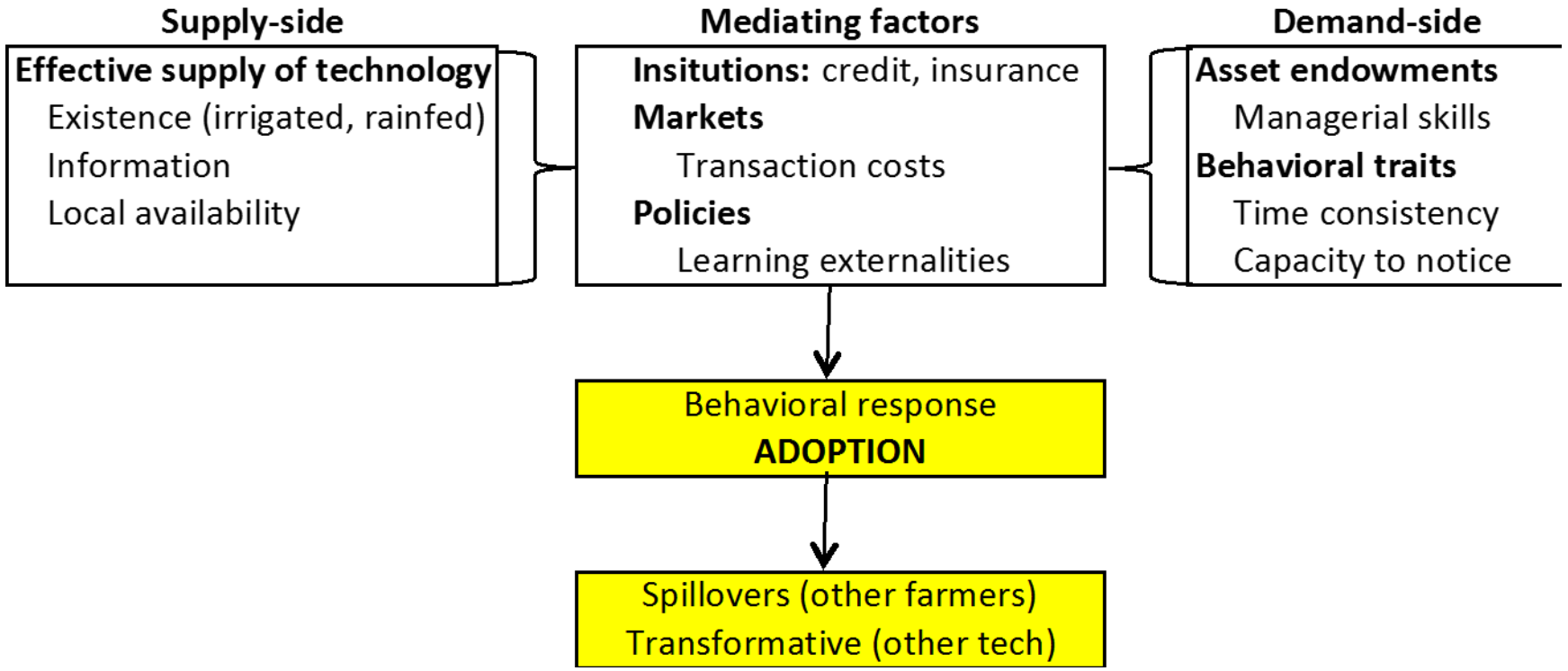


Bubble size: Rice area as a share of district area

- **Conclude**
  - **Fertilizer** use in SSA (rainfed conditions): Less than 15% of that in rest of the world, even though field experiments show that fertilizer can be profitable (Duflo et al.)
  - **Fertilizer** use in India's Eastern States: Low use and missing Green Revolutions under rainfed conditions

- **Puzzle**
  - **Why the low adoption** of productivity enhancing technological innovations in rainfed SSA and South Asia?
  - **Common features of context for adoption puzzle:** Smallholder rainfed (good potential, risky) agriculture:
    - High **complexity** and **risk**
    - High **hetereogenity** of farmer circumstances

# 4. The Puzzle of Low Adoption of Innovations in Developing Country Agriculture: Hypotheses




**Determinants of technology adoption**

## Outline of this Lecture

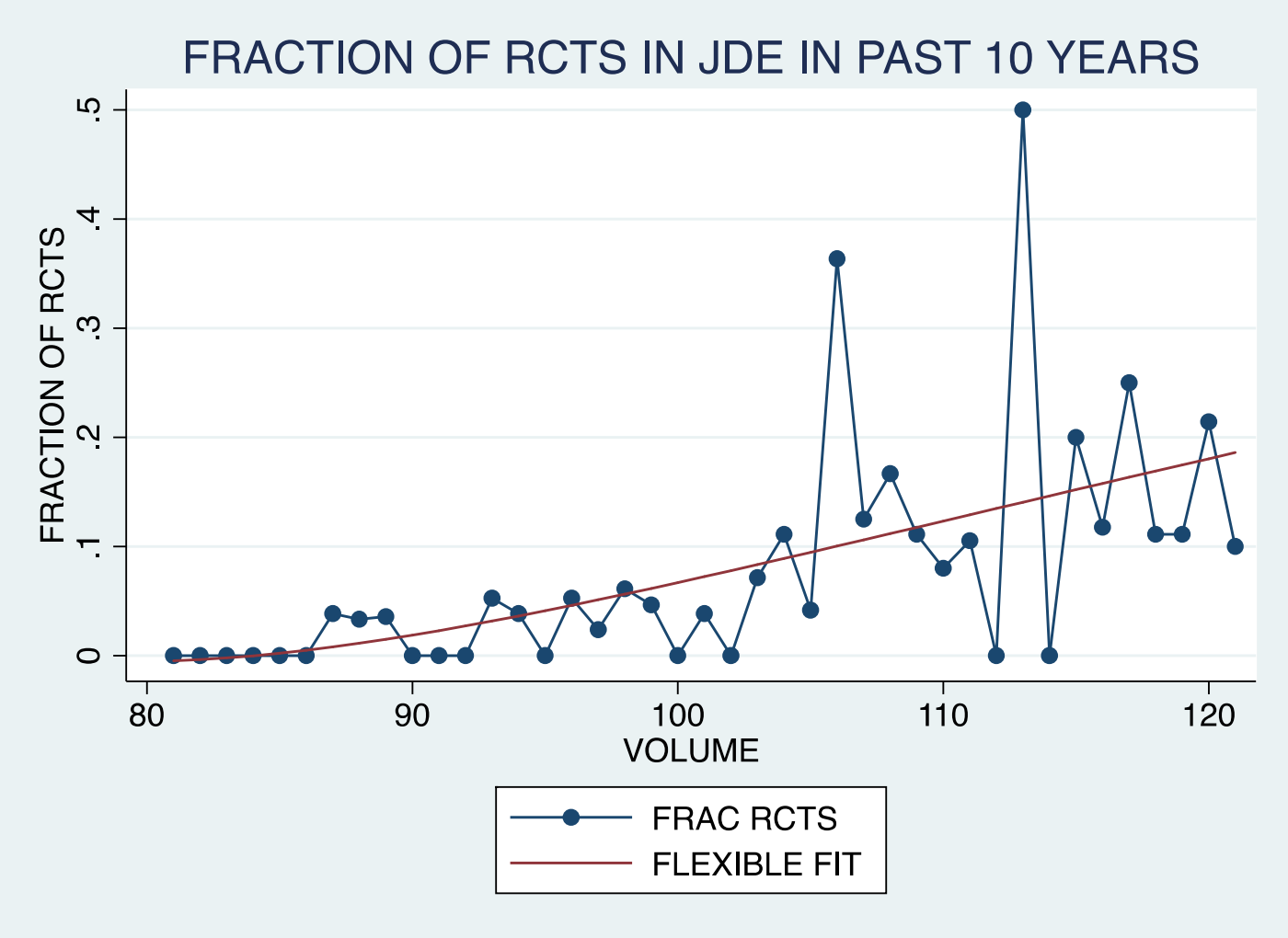
- Start with two observations
  - Observation 1: Decision-making by smallholder farmers in rainfed agriculture is highly **complex**
  - Observation 2: **Field experiments** in agriculture can help address the adoption puzzle
- Look at results from field experiments on adoption puzzle
  - Results for **demand-** and **mediating factor-**side constraints
  - Results for **supply-side** constraints on existence, information, and availability
- Conclusion: Resetting the focus on **effective supply**

# 5. Observation 1: Decision-Making in Agriculture is Highly Complex, Especially Smallholder-Rainfed

- **Agriculture**: Many inputs, stochastic shocks, heterogeneity, long lags, seasonality, many non-observables, non-separability, labor calendars, externalities, climate change
- **Education:** Similar complexity, but make choice of school and rely on teachers → Limited room for agency
- **Agriculture**: Many decisions, limited advice, large room for agency. Hence **slow learning** and **mistakes** expected
- **Conclude**
  - Implications for **research**: need local specificity/ adaptation, simplify decision-making
  - Implications for **extension**: need farmer learning/ understanding as opposed to imitation (Rodgers)
  - Implication for **value chains**: need local availability

# 6. Observation 2: Field Experiments in Agriculture Can Help Better Understand and Manage the Adoption Puzzle

- **Statistical identification of adoption decision:** difficult from **observational data** due to omitted variables, endogeneity, selection biases
- **Internal validity** using RCTs: strong when can be done (Athey and Imbens)
- **Setting up field experiments**: demanding, but growing practice (Glennester and Takavarasha):
  - Manage: Partnership with implementing agency
  - Design: Selection, power calculations, and inference
- **Boom in field experiments**, including addressing the adoption puzzle (ATAI): data on papers published in JDE using RCTs




**% RCT papers in JDE: From 0 to 20% in ten years**

(Peaks are special issues using FE)

- **Dealing with external validity** (Deaton)
  - Record **external conditions** for use by others, including potential selection effects (Chassang, Banerjee, Snowberg)
  - Engage in **replications** (role of IPA, 3ie)
  - Experiment on **causal channels** instead of policies/programs (Kling et al.)
- **Pragmatic/opportunistic choice of methods**: Often combine **FE** (RCT) with **game-in-the-field** (e.g., WTP) and **natural** experiments (e.g., program rollout or RDD)

- **Conclude**: **Pragmatic use of FE** in agriculture helpful to address the adoption puzzle

# 7. Results from Field Experiments: Role of Demand-Side and Mediating Factor Constraints

- **Results on demand side**
  - **Help behavior:** procrastinators need nudges to decide (set money aside for fertilizers) (Duflo et al.): can increase fertilizer uptake by up to 75%, **but** still low use (26%)
  - **Help notice** what matters in available information (Hanna et al.): focus attention on omitted variables to guide learning, **but** little known on how to do

- **Results on mediating factor constraints**
  - **Increase access to credit**
    - **But** results show **credit** unlikely to be the main constraint on adoption (Karlan et al.), and low take-up when available (Crépon et al.)
    - **Room for improvements**: customization to seasonality, post-harvest loans (Burke) and flexible collateral (stored crops), information on borrowers (credit bureau, rating, fingerprinting), pre-approved credit lines, IT services, nudges for repayment
  - **Increase use of index insurance** for better risk coping and risk management. Effective when used.
    - **But** results show very low demand without high subsidy
    - **Room for improvements**: reduce basis risk, risk layering, institution-level insurance

- **Improve access to markets**
  - Results show that poor **infrastructure** makes technology unprofitable for many (Suri); more **elastic demand** important for adoption (McIntosh)
  - **Room for improvements**: roles of infrastructure, contracts, IT platforms
- **Subsidies**
  - Needed when there are learning **externalities** or social benefits, but costly and sticky
  - **Room for improvements:** design and implement "smart" subsidies with stochastic learning (Cai et al.)

- **Conclude**: **Important progress** on demand and mediating factors **but** leaves adoption puzzle **only partially resolved**

## 8. Results from Field Experiments: Role of Effective Supply-Side Constraints

- Assumption that beneficial technologies are sufficiently **available for adoption** (placing the burden on the demand and mediating factor sides) may need to be reconsidered
- Direct observations in Eastern India/Bangladesh vindicate T.W. Schultz: smallholder farmers are "**poor but efficient**" with the assets they have and available technology
- Need increase **effective supply** for adoption

**Effective supply = Existence + Information + Availability**

Need all three for supply to be "effective"

- **Results** from our research on rice in Eastern India

# (8.1) Existence: Case of Flood-Tolerant Rice in Odisha

**New technology**: IRRI/CGIAR "Swarna-Sub1" = Swarna + Sub1 locus conveys flood tolerance → Reduces downside yield risk

**Research questions**

(1) **What is the risk-coping** value of Sub1? Measured by yield resilience effect in bad years

(2) **What is the risk-management** effect of Sub1? Measured by yield effect in normal years

**Research strategy:** Randomized distribution of Sub1 seed minikits to farmers (Emerick et al.)

**Observations**

- **Large floods** year 1: Measure **risk-coping** effect by flood duration
- **No floods** year 2: Measure **crowding-in** of other inputs and cultivation practices due to downside risk reduction



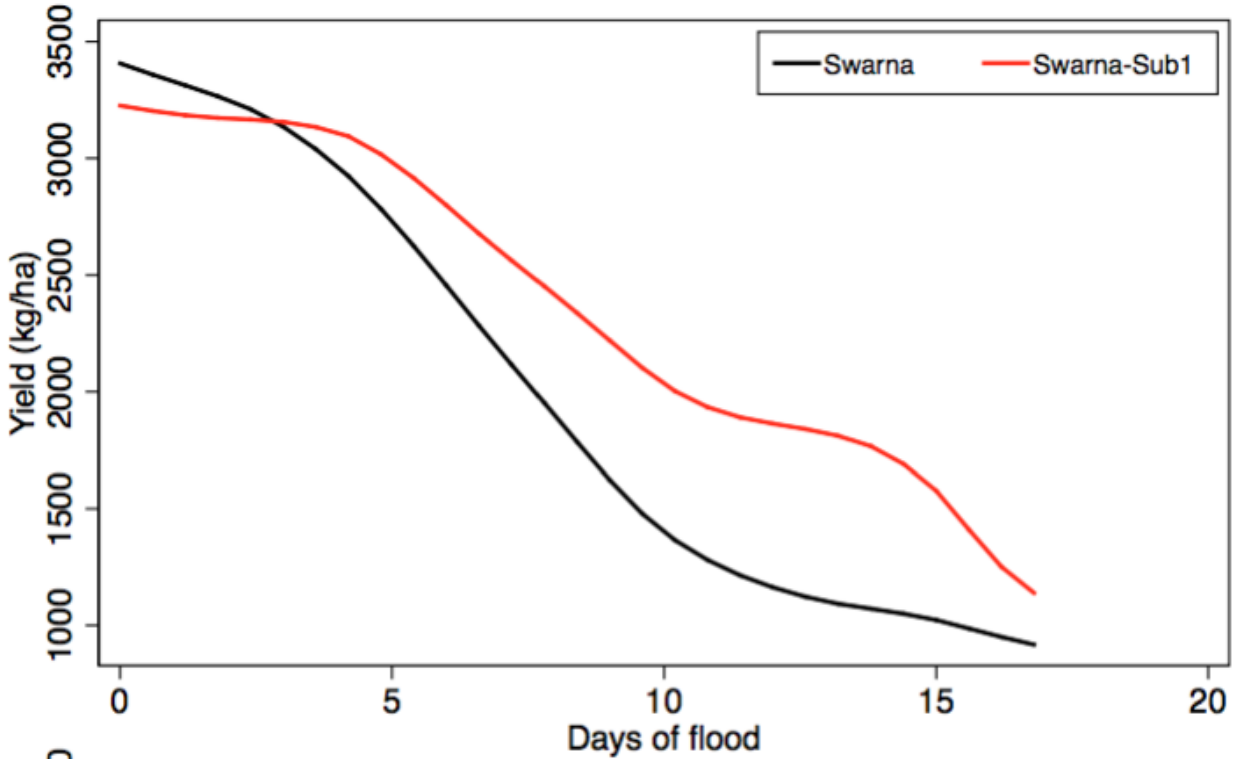

**Treatment group: Swarna-Sub1 minikit recipients**

**Exposure to shock: Farmer inspecting his flooded rice field**


**Yield outcome: Swarna and Swarna-Sub1 in farmers' fields after flooding**

# Results

## (1) **Risk-coping** value in flood year (Dar et al.)




**Yield by duration of flooding: Swarna vs. Swarna-Sub1**

No yield penalty with no flooding: **Superior technology**

45% **yield advantage** after 10 days flood. **Avoided yield loss** = 682 kg/ha

**(2) Risk-management** effect in normal year: effect on input use and cultivation practices

- 10% increase in planted rice area
- 15% less reliance on traditional varieties
- 11% increase in fertilizer expenditures
- 33% increase in use of labor-intensive transplanting
- 36% increase in credit use
- 280 kg/ha (10%) increase in yield in normal year

**(3) Combined risk-coping/management results**

- Agronomy: 682 kg avoided loss flood year
- Behavior: 280 kg gain in normal year due to crowd-in

→ **Risk-management** gains add 40% to **risk-coping** gains

→ **Benefit/Cost ratio** of 2.7 shows high return to adoption

**Conclude: Adoption increases with existence of technologies adapted to smallholders for good/risky rainfed conditions.**

Lessons learned:

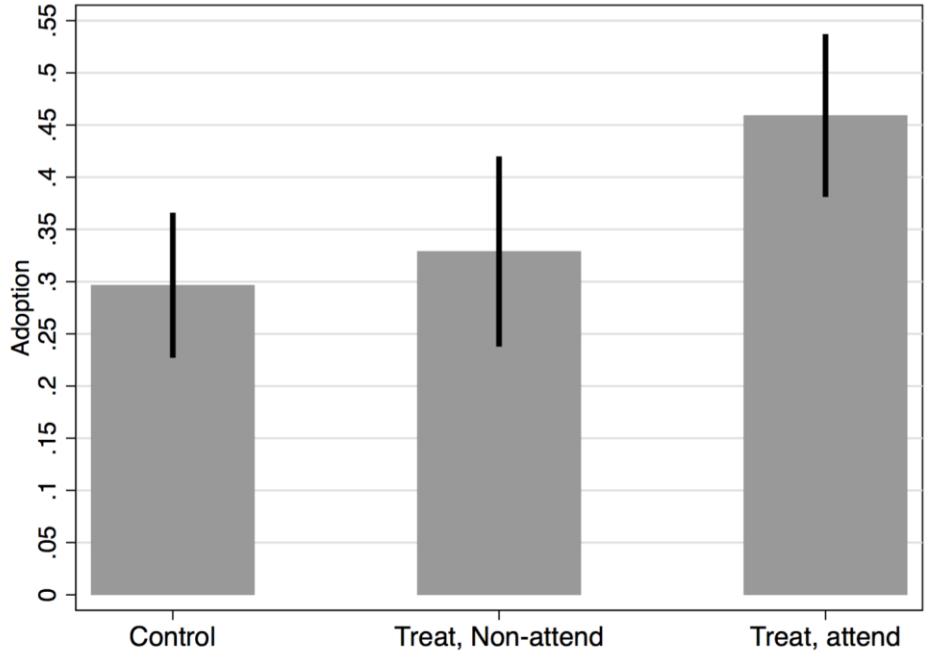
- **Technologies should be simple to adopt/use**: Sub1 identical to widely used Swarna, with no yield penalty
- **Gains from technological improvements should be large**: high B/C ratio from adopting and adapting
- **Technologies should be transformative** to induce change in behavior: adoption induces other adoptions
- Observe that when such technologies are available (case of Sub1), **demand follows supply at existing mediating factors**
- **But deficit of existence:** value of new seeds for drought and heat tolerance still uncertain

# (8.2) Information: Case of Extension Service for Sub1 in Odisha

- **Why current extension systems often do not work:**
  - **Training and Visit System**: **contact farmers** as intermediaries fail to convince others (Anderson et al.)
  - **Farmer Field School**: **student farmers** do not have the capacity to convey to others what they have learned
  - **India's Ag Technology Management Agency**: cluster **head-to-head demonstrations** and **farmer field days** do not demonstrate technology the way farmers use them
  - **Agricultural Knowledge Information Systems** (Neuchatel Initiative) using private **agents** in **value chains** often not in place: agro-dealers and commercial partners unable to serve as sources of information
- **Lesson learned: Complexity** of rainfed agriculture, **heterogeneity** of circumstances, and **changing** conditions require that farmers **learn to understand** technology, as opposed to Rodgers' imitation/threshold diffusion model

- **3 ways to increase the effectiveness of social learning**
  - **Choice of entry point** depends on issue to be resolved:
    - **Lead** farmers (can be self-selected based on WTP) for demo of **best use**
    - **Village-designated** or **voted in** farmers for maximum perceived **social benefits**
    - **Peer** farmers for maximum **similarity** (Tjernstrom)
    - **Opinion leaders** when **incomplete information**
    - **Members** of an organization or social group for **trust**
    - **Central** farmers for maximum **connection** with others (Beaman et al.)
  - **Give incentives to** contact farmers to diffuse knowledge to other farmers (BenYishay and Mobarak)
  - Use **Farmer Field Days** run by contact farmers using self-managed Head-to-Head demonstration plots to share experiences (Emerick et al.):

# Impact of Farmer Field Day (FFD) attendance on adoption




- RCT 100 villages with three entry points (Panchayat, village meeting, women Self-Help Group) and half with FFD
- Adoption in FFD villages increases from 30% to 42% (ITT)
- FFD effectiveness not affected by entry point

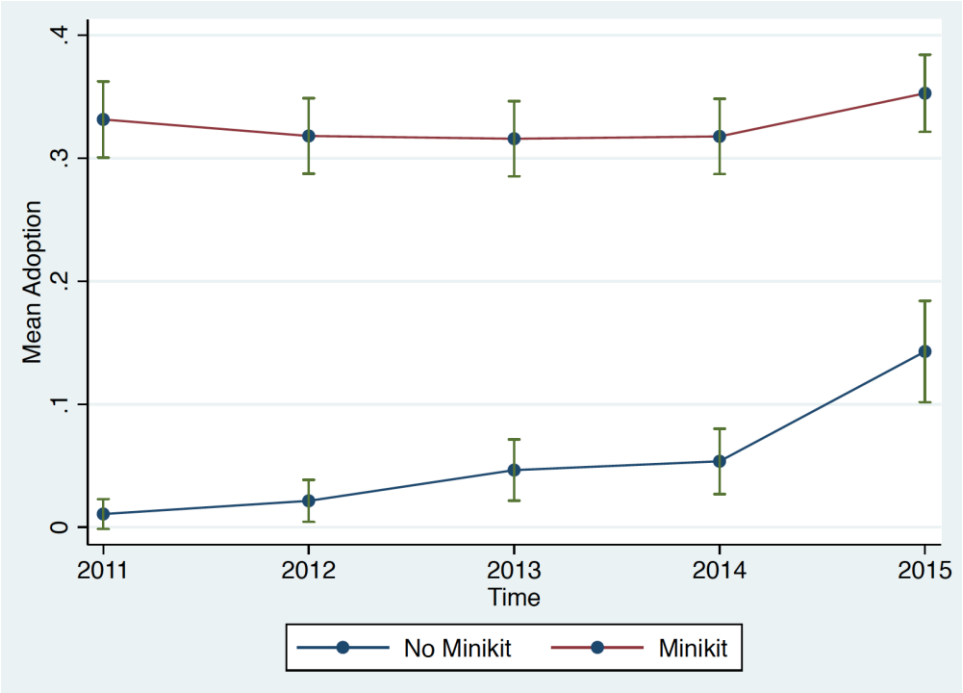
## Conclude: Increase information on new technologies

- Strategically **select early adopters** for social learning: Impact on diffusion modest, and reduced by heterogeneity
- Give **incentives** to demo farmers to diffuse information
- **Give information about technology to farmers the way they learn**
  - **H2H demonstration** plots managed **by** farmers under their **own** circumstances
  - Choice of **counterfactual** plot by demo farmer in **farmer field days** helps reveal his type to others
  - **Farmer field days** run **by** NGO and demo farmer
- As **value chains** develop, focus extension on **agro-dealers** and **commercial partners**, who can convey information to farmers as part of sales relations or commercial contracts

# (8.3) Availability: Case of Seed Supply for Sub1 in Odisha

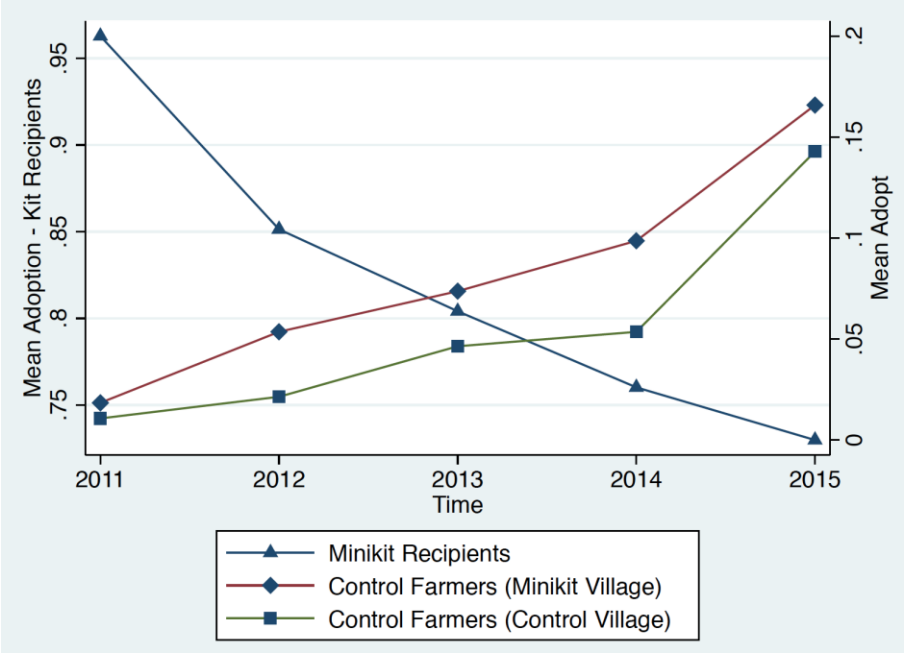
Why slow diffusion of Sub1 in Odisha even though it is a superior technology, easy to adopt?

"Long term" study of seed minikits RCT



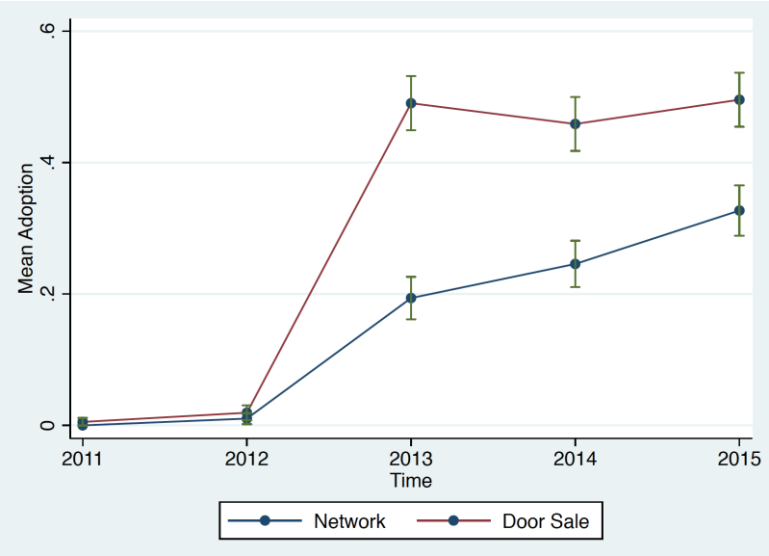

## Puzzle of low diffusion of Sub1 in treatment and control villages

- **33%** of farmers received minikits in treatment villages
- **No increase** in % use in treatment villages
- **Slow diffusion** in control villages: 14% in 4 years




## Lack of seed availability holds back diffusion

- In T villages: Loss of access to seeds among minikit recipients (from 97% to 74%) **compensated** by access to seeds by non-minikit recipients (control farmers) → Constant 33%
- Loss of access to seeds among minikit recipients due to harvest losses and seed management failures, with **no access to replacement**




**Even though, there is high demand for Sub1 seeds as revealed by door-to-door sales**

- Large gap between adoption through **door-to-door** sales (50%) and through **farmer-to-farmer** networks (30%)
- Persistence of gap indicates that **seed supply-side constraints** are important bottlenecks to long-term diffusion

- **Conclude: Improve local availability**
  - **Farmer-to-farmer** seed diffusion not effective: segmented social networks, no incentives to diffuse, lack of quality certification/trust
  - **Door-to-door** sales reveal high unmet effective demand (Emerick)
  - **Agro-dealers** and **interlinked contracts** in **value chains** need to be put into place as sources of availability

# (9) Conclusion: Resetting the focus on effective supply

- **Adoption puzzle** is lack of Green Revolution for smallholder farmers in rainfed agriculture (SSA, Eastern India): symptomized by low use of fertilizer due to low productivity technology
- Pragmatically used **field** experiments can be useful to address the adoption puzzle (Jack-ATAI)
- Field experiments have emphasized **lack of demand** and **mediating factor constraints** in addressing the **adoption puzzle**: behavior, credit, insurance, markets. Useful, but puzzle **remains.** More experimentation needed
- Results also show that lack of **effective supply** of technology for rainfed areas is a major limiting factor to technology adoption: **existence**, **information**, **local availability**

- **Policy implications**
  - Invest more in **existence** of technological innovations for **smallholder farmers under rainfed**: New technologies with large benefits (e.g., high B/C from risk reduction) and fit for adoption (e.g., simple to adopt, induce transformative behavior)
  - Give more **information** about technology to farmers the way they **learn**: redesign the **extension** system for learning, increase effectiveness of **social learning**, and promote emergence of informative **agents** in value chains
  - Increase **local availability** of technological innovations by fixing the **seed supply** system and promoting the role of marketing and contractual **agents** in value chains

- **Recommendations to donors**: Reset priorities toward **increasing the effective supply of innovations**
  - **Existence**: Increase support to **discovery-type research** as an **international public good**
    - In spite of **CGIAR successes and reforms** (CRP), **only 25% of** (~$1b) **budget** goes to discovery research: need resolve collective action problem
  - **Information**: Revalorize investing in **extension** to help farmers **learn to decide.** Extension chronic poor child of foreign aid: costly mis-understanding
  - **Availability**: Invest in supporting **private** agents in **value chains** for information and availability: more attention to emergence of private sector

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