





# The Agricultural Technology Adoption Initiative (ATAI): Emerging Insights

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### Motivation

~450 million smallholder farming households (~2 billion people), largest segment by livelihood of those living on <\$2 per day.

Agricultural technologies exist, but the Green Revolution did not transform agricultural productivity everywhere

- When technology adoption fails -- Why?
- How can we improve smallholder farmers' profits and welfare?
- What policy levers can help?



CGAP 2016 using FAO data; Infographic Data Source: World Development Indicators, FAO via the World Bank ATAI | EVIDENCE IN AGRICULTURE: RISK |

### What is hampering technology adoption?

### Inefficiencies constraining technology adoption

- 1. Credit markets
- 2. Risk markets
- 3. Information
- 4. Input and output markets
- 5. Labor markets
- 6. Land markets
- 7. Externalities

adai AGRICULTURAL TECHNOLOGY ADOPTION INITIATIVE www.atai-research.org

Since 2009 have funded

- 48 evaluations in 15 countries in South Asia and Africa
- >100 affiliated researchers
- each study with field partners

Co-managed by:



at UC Berkeley





### RCTs: Rigorous Impact Research

Important to identify "causality"

- Lessons for program and policy design
- Supports results-based management of programs

**RCTs** have become a widely used methodology

- Not only an academic approach
- Strong demand by development partners (One Acre Fund, CGIAR, Technoserve, etc.)

**RCTs in economics** help in particular understand the role of **behavior** and **institutions** (agricultural systems) in program/policy outcomes.

Developing research and policy partners

ATAI PIs have worked with over 50 partners on evaluations



### Since the start of ATAI...

Category	Total
Farmers surveyed	111,351
Female farmers surveyed	47,845
ATAI Awards	61
Unique ATAI projects	48
Countries with ATAI projects	15
Working papers	13
Published papers	7

## Emerging Insights on Constraints to Adoption

- 1. Credit markets
- 2. Risk markets
- 3. Information
- 4. Input and output markets
- 5. Labor markets
- 6. Land markets
- 7. Externalities

Emerging Insights: Credit Markets

### Credit constraints in action



There is limited credit available



Farmers struggle to save income from one harvest to the next



Farmers don't have collateral to back a loan



Farmers lack financial literacy

### Preview: credit for smallholders

- Farmers' credit needs are different from urban microcredit customers
- Take-up of traditional credit products is often low
- Successful credit interventions
  - Tailor products to reduce costs and risk for lenders
  - Account for seasonal variation in income (and prices)
- Credit constraints exist, but may not be the primary barrier to increasing profitability

## Hard to push financing to agriculture

- Lenders dislike agricultural loans
  - Pervasive default risk due to correlated weather shocks
  - Costs of servicing clients are high, particularly for smallholders
  - Smallholder farmers have no credit histories; land tricky as collateral
- Borrowers appear to have low demand for loans
  - Profits in farming may be low absent complementary investments
  - Risks of unavoidable default are high
- Few self-sustaining agricultural credit markets for smallholders
  - Urban microfinance not suited; difficulties in transplanting it to agriculture
  - Few agriculture-specific products
  - Low demand from farmers

### Take-up is low



Morocco: 17%, with no other lenders in the area



Sierra Leone: 25%, i.e. 50% lower than break-even rate



Mali: 21%, compared to full take-up of cash grants

Beaman et al. 2014, Casaburi et al 2014, Crepon et al 2015

### Impacts on agricultural activity, inconclusive on profits

- Mali: Households offered loans spent more on fertilizer, insecticides
  - Cash grants increased farm profits; loans increased value of output but not profits
- Morocco: Loans used to invest in agriculture and purchase cattle or sheep
  - > Agricultural income increased, other sources decreased
- Kenya:
  - Farmers switched to higher-value export crops, >>> market collapse eliminated any potential profits
  - Farmers stored or bought grain when prices were low, sold when prices rose >>> increased profits
- Malawi: Farmers allocated more land to paprika, a cash crop
  - Profit estimates positive but imprecise and not statistically significant

Beaman et al 2015; Crepon et al 2015; Ashraf et al 2009; Burke 2017; Yang et al 2012

## Interventions to address credit constraints

### Supply-side

- Microfinance model is
  inappropriate for farmers
- Banks often do not lend to the agricultural sector

### **Demand-side**

- Lack of credit may not be the primary binding constraint
- Take up of credit is low

#### Interventions

- A. Improved information about borrowers
- B. Flexible collateral
- C. Account for seasonal variation (production, prices)
- D. Saving to invest: Labeling, Commitment

Ashraf et al. 2006; Banerjee et al. 2013; Basu & Wong 2012; Beaman et al. 2014; Boucher et al. 2008; Burke 2017; Carter et al. 2013; Casaburi et al. 2014; Crepon et al. 2015; De Janvry 2010; De Laat et al. 2016; Duflo et al. 2008; Fink et al. 2014; Gine et al. 2010; Gine et al. 2011; Karlan et al. 2010; Matsumoto et al. 2013; Tarozzi et al. 2013

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### Improved information about borrowers

Lack of information makes banks unwilling to lend

- hard to assess creditworthiness
- cannot credibly threaten to cut off future credit

Credit bureaus

- transformative institution when lender info is poor, competition high
- can allow borrowers to substitute 'reputational collateral' for physical collateral

Alternate technologies such as fingerprinting borrowers

• biometric identification cannot be lost, forgotten, stolen

McIntosh & Wydick 2006; de Janvry et al. 2010; Gine et al. 2011

### Flexible collateral

- Land may be an unacceptable form of collateral in smallholder agriculture
  - Banks: titles unclear, seizure under default costly & difficult
  - Farmers: Loss averse
- However, many large agriculture investments can be selfcollateralizing (leasing)
- Warehoused grain as collateral

Pender 2008, Basu and Wong 2012; Burke 2014; Casaburi et al. 2014

### Rainwater harvesting tanks in Kenya

- Tanks for dairy farmers to collect water for cattle
- Variations in loan offers
  - Standard: 100% secured
  - 25% deposit, tank as collateral
  - 4% deposit, 21% pledge from guarantor, tank as collateral
  - 4% deposit, tank as collateral

De Laat et al. 2015



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### Rainwater harvesting tanks in Kenya



### Account for seasonal cycles of production & prices

- Aggregate (not idiosyncratic) risks
- Negative correlation of production and prices
- Seasonal cycles:



### Designing products for seasonality

• Delaying repayment of loan until after harvest

• Loans for consumption during "hungry season"

 Storage loans to allow farmers to take advantage of price fluctuations

• Savings products to save from harvest until planting time

### Harvest-time storage loans in Kenya

- Loans allowed farmers to:
  - Buy/keep maize at low prices
  - Store while prices rose
  - Sell later at higher prices
- Temporal arbitrage increased profits, ROI of 28%
  - Profits concentrated in areas where fewer farmers were offered loans
  - See effects of credit intervention on smoothing seasonal price fluctuation: benefits program non-recipients (GE effects)



#### <u>Burke 2017</u>

# Maybe credit is not the binding constraint

In Northern Ghana: compared cash grants, weather index insurance, or combination

- Investment and activity increased about equally in cash groups and insurance groups
- But when risk constraint relieved, farmers were able to find credit from other sources

In Odisha, India: farmers increase borrowing in response to risk-reduction

• Early in growing season of the second year after shifting to flood-tolerant rice production, farmers are 36% more likely to utilize credit from local co-ops

Karlan et al 2013; Emerick et al. 2015



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### Summary: Credit

- Credit is key to investment, but many markets are too risky and too lowreturn to be viable without additional investment
- Farmers' credit needs are different
- Take-up is often low
- Complementary institutions critical for 'moving up' with credit: credit bureaus, credit registries
- Some promising ways of using information, timing, and new types of collateral to unlock credit
- Access to credit affects farm activities, but mixed evidence on profit suggests other constraints may be binding
  - Risk is a dominant issue for credit; insurance and credit likely to need to be grown hand-in-hand

## Emerging Insights: Risk

### Preview: risk

### Risk matters

- Most investments in improved inputs increase the financial risks of farming
- Farmers make conservative production decisions to self-insure

### Some potential solutions to risk:

- 1. Financial instruments: Weather Index Insurance (WII)
  - Low demand for micro-insurance, in particular weather index insurance
- 2. Technology that structurally decreases risks
  - Risk-mitigating crops, irrigation: Promising early results on risk-mitigating crops
- 3. Credit products with (explicit or implicit) limited liability in case of weather shocks
- 4. Public sector safety nets

### How does risk constrain adoption?

- Agriculture is inherently risky activity
  - Weather and disease risks are aggregate, affecting all farmers in geographic area
- Farmers may lose large portion of harvest to extreme weather event
- Without any way to mitigate or insure risks, investment in crops or technologies appears to be an unsafe gamble
  - Higher-value crops may also be more sensitive to weather
- Exacerbated by risk aversion and ambiguity aversion

# A decade of experimentation on weather index insurance

- 10 randomized evaluations in various contexts
  - India, Ethiopia, Ghana, Malawi
  - Differences in crops insured, conditions that triggered payout, etc.
  - Effects of discounts, other encouragements to purchase insurance
  - Effects on production decisions



#### <u>J-PAL 2016</u>

## Demand was low at market prices but increased with large discounts



Karlan et al 2013; Mobarak & Rosenzweig 2012; "Make it Rain"

### Insured farmers took more risks on their farms

- When given subsidized insurance, farmers took on greater production risks
  - Andhra Pradesh: Fewer subsistence crops, more cash crops
  - Ghana: More land planted to maize, greater fertilizer use
  - Tamil Nadu: Shift from drought-tolerant varieties to high-yield varieties
  - China: Insurance for sows caused farmers to move into this risky but highly profitable crop
  - Mexico (CADENA): insured farmers plant more the year after a shock than non-insured farmers
  - Kenya (IBLI): insurance helps pastoralists avoid decapitalizing livestock in response to drought

<u>Cai et al. 2015; Cai 2013; Cole et al 2014; Karlan et al. 2013; Mobarak & Rosenzweig 2014; de Janvry et al 2016;</u> Janzen & Carter 2013

# An alternative: risk-mitigating crops and technologies

- Agricultural R&D on varieties that tolerate flood, drought, salinity
  - Increasingly important with climate change
- Swarna-Sub1 is a flood-tolerant rice variety
  - No yield penalty in normal conditions
  - Researchers tested effect in reallife conditions in Odisha, India



## Scale-up would benefit marginalized populations the most



Note: Error bars represent 95% confidence intervals. Stars (\*) note statistical significance from control group.



### Risk: evidence-based insights

- Standalone weather index insurance can increase risk-taking in production, but has limited commercial viability at market prices
  - Low demand at market prices (16%; 50% subsidy increases demand to 38%)
  - Linking credit with insurance: mixed results, low demand
  - Demand increases when farmers observe payouts
  - Improving financial literacy/ understanding increases take-up, but cost of training much higher than premiums
  - Impacts: increases risk-taking in production decisions
- New risk-mitigating crop varieties a promising alternative

Cai et al. 2010, Cai 2013, Cole et al. 2013, Cole et al. 2014, Dar et al. 2013, Gine & Yang 2009, Gunnsteinson 2014, Janzen & Carter 2013, Karlan et al. 2010, Karlan et al. 2012, McIntosh et al. 2013, Mobarak & Rosenzwig 2012, Mobarak & Rosenzwig 2014

### Summary: Risk

- Risk is a constraint for smallholder farmers
- Commercial index insurance targeted directly at farmers unlikely to solve the problem
  - Price, distrust, lack of financial literacy, basis risk
- Alternatives that should be tested to help farmers manage risk
  - Rethink insurance: provide subsidized policies as an alternative to cash transfers
  - Sell to institutions such as ag lenders
  - Improving data to align index triggers & experienced losses at farm
  - Promising preliminary results on risk-mitigating crops

Emerging Insights: Information

### Why do farmers need information?

- Learning about a new agricultural technology is a fundamentally hard learning problem
- Information helps famers assess novel technologies, their risk profile and potential profitability
- If a farmer is to use a new technology effectively they need to know:
  - That it **exists**
  - Something about its benefits and costs
  - How to use it effectively

### Preview: Information

- Agricultural extension is the most common model: Use of services is low, limited evidence of impact
  - May promote unprofitable technology (focused on yields)
- Extension can be effective when
  - Overcoming a behavioral bias (procrastination)
  - Introducing new or novel technologies (risk-reducing seeds)
  - Revealing hidden qualities of ag technology
  - Providing accessible, tailored, and timely information
  - How to mobilize networks (similar farmers, multiple farmers)

Beaman et al. 2015, BenYishay & Mobarak 2014, BenYishay et al. 2015, Blair et al. 2013, Casaburi et al. 2014, Cole & Fernando 2012, Duflo et al. 2008, Duflo et al. forthcoming, Hanna et al. 2012, Islam 2014, Kondylis et al. 2014, Tjernstrom 2015, Waddington et al. 2014

## Potentially big costs to ignoring training w/ new tech

Upland NERICA Rice introduced in Sierra Leone

- In villages where seeds coupled with extension, yields increased by 16%
- In villages where seeds were simply distributed, yields fell

Without extension, hard for farmers to learn about variety's yield potential, and necessary agronomic practices to reap benefits

Glennerster and Suri, forthcoming



### Improving extension services

- Incentives may improve adoption
  - Extension officers
  - Lead farmers
- Feedback on extension may help
  - Improves satisfaction
  - Improves knowledge in certain circumstances
- ICT to reach farmers directly
  - Interventions using mobile phones to provide information to farmers have been shown to increase adoption and improve yields

BenYishay and Mobarak 2015, Ben Yishay et al. 2015, Jones and Kondylis 2015, Masset and Haddad 2014 Cole and Fernando 2016, Casaburi et al. 2014

### Mobile Phone-Based Agricultural Extension in India

- Gujarat, India
- 2011-2012
- Center for Microfinance

400 mobile

extension

• Awaaz.De

400 mobile + traditional extension

1200 cotton farmers

400 comparison

Cole and Fernando 2012, Cole and Fernando 2014

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### Mobile Phone-Based Agricultural Extension in India

• Traditional extension had no effect

- High take up and use of mobile platform
- Switch to more effective pesticides
- Increased adoption of cumin
- Some evidence of increased yields in cotton
- Estimated return of \$10 per \$1 spent

Cole and Fernando 2012, Cole and Fernando 2014



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### Precision Agriculture for Development (PAD) Gujarat, Kenya,

Ethiopia, and others underway

#### Based on India and Kenya ATAI RCTs and ongoing followups:



#### **System Characteristics**

Hybrid model data generation (experts and farmers) Constant experimentation and learning Farmer feedback – two way communication

### Target Behavioral Barriers

- Help farmers overcome procrastination
  - Reminders to use inputs
  - Well-timed information delivery
- Help when information is novel, complicated, or highly context-specific and learning is hard
  - Farmer-led experimentation to experience firsthand applied to their personal conditions
  - Simple tools to focus and aid learning

Duflo et al. 2011, Casaburi et al. 2014, Cole and Fernando 2014; Hanna et al. 2012, Duflo et al. forthcoming, <u>Islam 2014</u>



## Social learning

- (Much) extension relies on social learning for the last mile
  - Too expensive to train everyone who you hope to reach
- Lots of good evidence that social learning happens in agriculture
- Key question: How to design extension services to maximize social learning?
  - Breadth versus depth of treatment with limited resources



Ben Yishay et al. 2015, Beaman et al. 2015, Tjernstrom 2015, BenYishay and Mobarak 2013

## Social learning

- The messenger matters
  - A farmer is more likely to demand a new technology if a greater proportion of his/her network is demonstrating it
  - Lead farmers most closely resembling target farmers were more effective at promoting a new technology
- Designing extension systems so that some farmers will be able to observe multiple data points is critical
  - need multiple demo plots or lead farmers per village – and intensity of exposure may be more important than equity



Ben Yishay et al. 2015, Beaman et al. 2015, Tjernstrom 2015, BenYishay and Mobarak 2013

### Summary: Information

- A lot of specific information is necessary for farmers to make informed decisions on technology adoption
- Information is only useful to the degree that it is profitably actionable
- Business-as-usual extension is often ineffective
- Improved extension may be critically important for new tech adoption:
  - When tech is not readily understood, and/or is complicated by heterogeneity
- Extension may be improved
  - Incentives and Feedback
  - ICT; Adapting the pedagogical model (timely, accessible, tailored info)
  - Selecting the messenger, leveraging social networks

Emerging Insights: Input & Output Markets



### Preview: input/output markets

- Price information has limited positive effects on farmers, though other members of the value chain may benefit
- Infrastructure investment can decrease transport and input costs
- Preliminary and ongoing work on:
  - Contracts
  - Market linkages
  - Crop-quality and pricing in supply chains

### Input and output market inefficiencies

Farmers may be unable or unwilling to adopt new technology due to barriers within:

&

### **Input Markets**

- Missing or incomplete supply chains
- Unprofitably high input prices

### **Output Markets**

- Lack of access to additional markets
- Low prices for yields, including high quality crops

### Impacts of price information

Theoretically:



Evidence shows:

- Members of value chains who can act on price information can benefit
  - Traders and fishermen saw reductions in price dispersion, potential profit improvements
- Unlikely to affect farmer incomes or price levels
  - Farmer lack bargaining power
  - Transport costs remain high
  - Farmers may change behavior, but on average no gain for farmers

### Market Linkages

Shallow markets with inelastic demand Lower profits for farmers adopting yield-increasing technology

Improve access to deeper markets

New technology brings higher profits as well as higher yields

### Building Market Linkages in Uganda

- Isolated, shallow markets: imbalances in food supply, limited market opportunities
- Can new contract farming services and an ICTenabled trader alert system improve market depth in favor of smallholders?
  - Overcoming transaction mismatches through market information and "e-bulking"
  - Experimental cross-cuts with financial services, price information
- Impacts on input use, yields, market linkages, sales volumes, price dispersion, profits?
  - Impacts of contractual risk and credit in determining the probability of successful contracting?

Bergquist et al., forthcoming

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### Market Price Data



### Integrating Value Chains to Improve Food Safety in Kenya

- Severe health consequences of Aflatoxin
- Effective preventative technologies are available, yet rarely adopted by smallholders
  - Contamination risk to own food supply
  - Also prevents smallholders' access to potentially higher-value output markets
- Rigorously evaluating adoption of preventive biocontrol Aflasafe KE01 and mobile dryers, and ex-post testing
  - When access to output markets facilitated: food safety conditional purchase commitment from a formal sector buyer
  - Whether introduction of aflatoxin testing reduces aflatoxin exposure among the poor

Hoffmann et al., forthcoming

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### Expected Market Reforms and Crop Quality in Senegal

- Onions would be sold based on weight (not volume), with quality certification
- Information campaign about upcoming reform and training on quality-enhancing cultivation
  - improved onion quality: more qualityenhancing fertilizers, more onion sorting
  - led to substantial income gains (10.7 percent increase)
- Despite gains, market reform not sustained given traders' resistance

Bernard et al. 2017

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### Understanding trader-farmer relationships is key

- These relationships can affect farmers' selling decisions
  - Sierra Leone: palm oil producers were hesitant to break relationships with traders by storing harvests rather than selling at low prices
  - India: potato farmers' ex-post bargaining relationships with traders limited the effectiveness of price information provision
- Not "just" intermediaries, traders can stand-in for financial institutions
  - Sierra Leone: cocoa market traders build committed relationships with producers through credit provision. Cocoa quality premiums aren't passed through to producers via better prices, but credit provision increases
  - Kenya: dairy farmers preferred to sell to co-ops and receive lower, bulked payments (like savings) than sell to traders and receive daily payments

Casaburi et al 2014; Mitra et al 2015; Casaburi et al 2017; Casaburi and Macchiavello 2016

### Summary: input/output markets

- Price information:
  - has limited positive effects on farmgate prices, suggesting asymmetric info not a source of market power for traders
  - More evidence that info leads to convergence across markets. Still leads to welfare benefits for farmers.
- Infrastructure investment can decrease transport and input costs
- Recent, preliminary, and ongoing work on:
  - Contracts
  - Market linkages
  - Crop-quality and pricing in supply chains

### **Overall Summary**

- Many interventions that improve yields do not subsequently see widespread adoption. Why not?
  - Rainfed agriculture is challenging, and can have important variation over time and space, which can hamper access to tech and learning
  - Protecting farmers from risk is key, and should be considered alongside financial service provision efforts
  - Financial services need careful, tailored design to help farmers, and should not be presumed sufficient to make farmers profitable
  - Training and info services should share new information in a timely and tailored way, and selection of the "messenger" is important
  - Price information is unlikely enough on its own there is work to be done to understand relationships with intermediaries, and how to strengthen value chains for improved output market access
- RCTs are an excellent way to figure out what does not work, as well as what does!



## Thank you

For questions or requests email: atai@povertyactionlab.org

