The Complexity of Multidimensional Learning in Agriculture

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Outline

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Motivation

- Inspired by lessons from when we tried to construct an index of agronomic knowledge:
  - How many seeds per whole, depends on the type of seed
  - Planting in line only useful if fertilizer is applied
  - biological nitrogen fixation is very cost effective only if no chemical N is provided, while combining it with a P source increases its effectiveness
  - returns to fertilizer depend on the use of weed-resistant seeds, but only when those weeds are present
- We felt that current learning models don't do justice to such level of complexity due to this multidimensionality
- Let's put ourselves in the farmers' shoes and take seriously this complexity faced by farmers?

Research Questions

- How does exposure to new information regarding new (more sustainable) input combinations affect different forms of learning ?
- How does this exposure affect farmers' decisions and profits over time?

Contributions to the literature

- Relates to papers testing information related interventions, such as demonstration plots and field days (Crane-Droesch 2018, Emerick and Dar, 2021), extension services or trainings (Kondylis et al. 2017, Beaman et al. 2021; Aker and Jack, 2023), input subsidies (Carter et al. 2021, Gignoux et al. 2023) or input quality (Bold et al, 2017).
- Most connected to paper that try to learn about the learning either in real life (Hanna et al. (2014), Nourani 2019) games or virtual environment (Barham et al. 2015, Tjernström et al 2021., Conlon et al. 2022)
- This paper focuses on multidimensionality of learning on new inputs and practices, in the presence of complementarities and substitutability as possible key constraint to technology adoption: adopting a new input may require many adjustments in other input and practice decisions, which are costly to figure out.
- Provide framework relevant to many papers with evidence on complementarities (Emerick et al. 2016, Ghosh et al. 2018, Jones et al. 2022)
- Speaks to a debate on the role of High Skill Farmers in rural areas (Young 2013, Gollin 2014)

A comprehensive view of the learning process

- Exogenous variation in exposure to learning (through participation to agronomic trials)
- Detailed surveys on know-how tests, beliefs about returns, practices, input use, networks and monitoring data from trials.
- Dynamics over time : data collection in 6 consecutive seasons
- Differentiate by skill level
  - Rich baseline skills & ag know-how measures (see Laajaj & Macours, JHR 2021)
- Theoretical model with bayesian learning over a multi-dimensional production function

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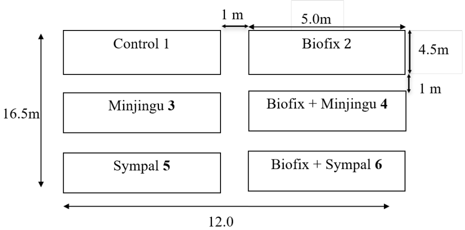
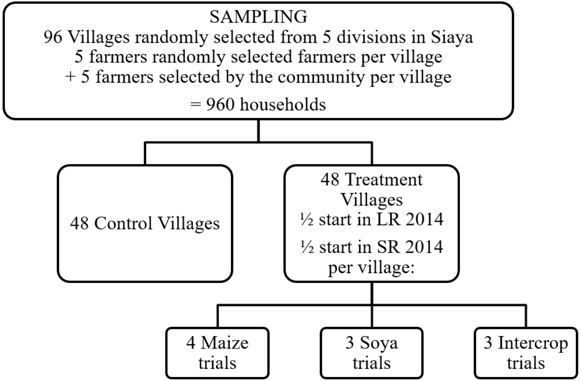
Context and intervention: The IITA agronomic trials

- In Siaya, Western Kenya. Intervention = participation to agronomic trials with the International Institute for Tropical Agriculture (IITA), 2x3 design, testing different combinations of chemical fertilizers, bio-fertilizers and seeds.
- Real trials used for ag research on Integrated Soil Fertility Management (ISFM).
- ISFM aims at increasing efficiency while bringing environmental benefits through the right combinations of inputs and practices and local adaptation (knowledge intensive).
- 3 possible crops: maize, soya or intercrop (maize + soya)



Sampling and Study Design



- Village selected through a public lottery
- Stratification: by geografical area and skills proxy (available ex-ante)

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Specification for Heterogeneous Effects by Skill Level

$$Y_{it} = \beta_0 + \alpha T_{it} * LSF_i + \beta T_{it} * HSF_i + X_{it}\gamma + \epsilon_{it}$$

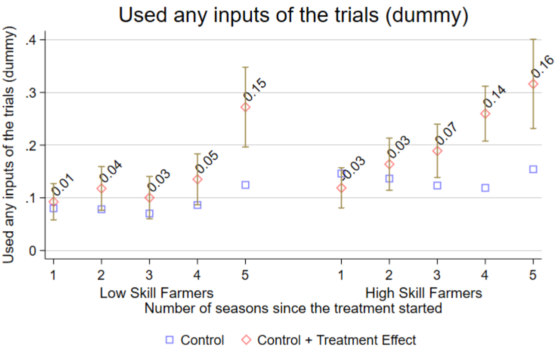
- LSF_i: Low Skill Farmers & HSF_i: High Skill Farmers
- X_{it} is a vector of controls
- α is the treatment effect for LSFs & β is the treatment effect for HSFs
- And to estimate dynamic heterogenous effects

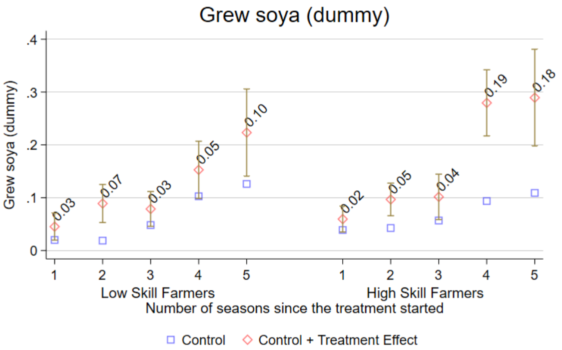
$$Y_{it} = \alpha_0 + \sum_{s=1}^{s=5} \alpha_s T_{it}^s * LSF_i + \sum_{s=1}^{s=5} \beta_s T_{it}^s * HSF_i + X_{it}\gamma + \epsilon_{it}$$

where T_{it}^s is a dummy $= 1$ if the treatment started s seasons ago

Input Adoption and Losses in Profits

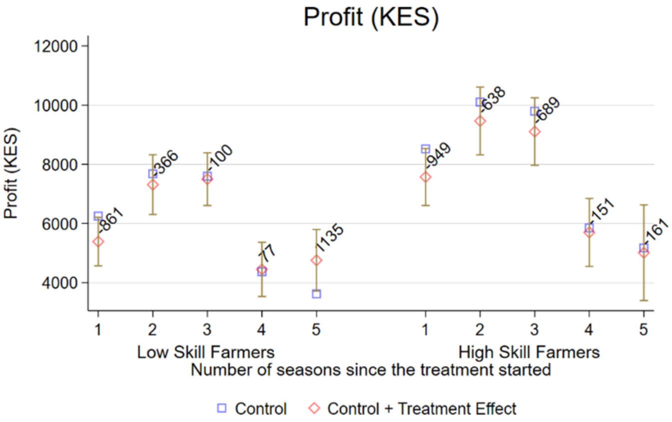
Input and Crop Adoption





- Modest but significant adoption that grows over time
- HSFs are faster but LSFs tend to catch up

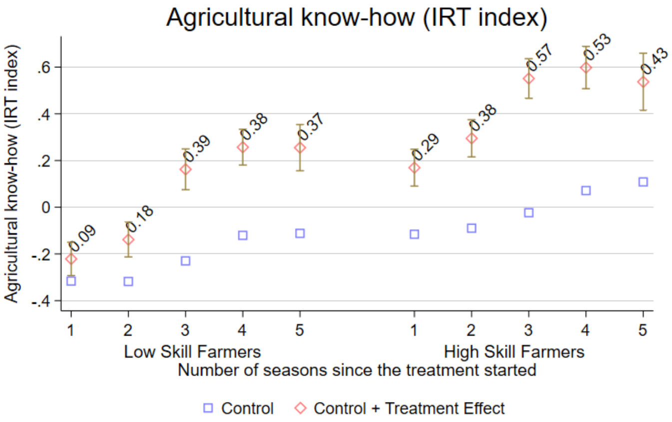
Profit Dynamic Effects



- Significant loss in profit at the beginning
- starts being positive at the end for LSFs

Different Skills, Different Learning Dynamics

Treatment effects on agricultural know-how by seasons treated



- All farmers learn significantly
- HSFs learn faster and more

Some Puzzles

- Why does the adoption of inputs increase over time if profits went down?
- How to explain a divergence in know-how between LSFs and HSFs, whereas most standard models would predict a convergence in know-how

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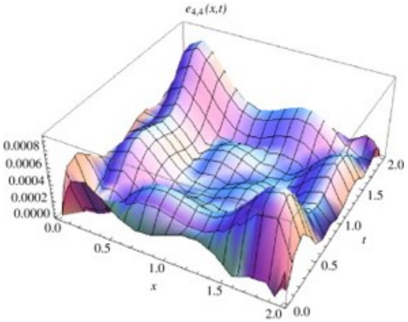
Bayesian Optimization over Multiple Dimensions

- A true profit function: $\pi_i = f(X_t) + \epsilon_t$
- X_t are the n inputs and practices: some may be exogenous, but many are endogenous.
- A risk averse farmer sequentially chose X_t to maximize intertemporal utility
- $f(X)$ is non-parametric but smooth, allowing a Bayesian update at an observed point and its vicinity.
- HSFs learn faster



Summary of Key Propositions:

- Tradeoff between exploration and exploitation traditional in bandit problems
- 3 possible strategies:
- Leads to 3 possible strategies: a)"optimal step size exploration" b) exploitation and c) "jumping into the wild"

1. with enough time, farmers convert to the local maximum (but not global)
2. A curse of dimensionality results from complementarities and substitutabilities between inputs
3. A new signal can trigger a "jump into the wild"
4. When jumping into the wild, short-term losses in expected utility can be tolerated, and even more so for a HSF than a LSF
5. A LSF can obtain more valuable information from observing a HSF than another LSF

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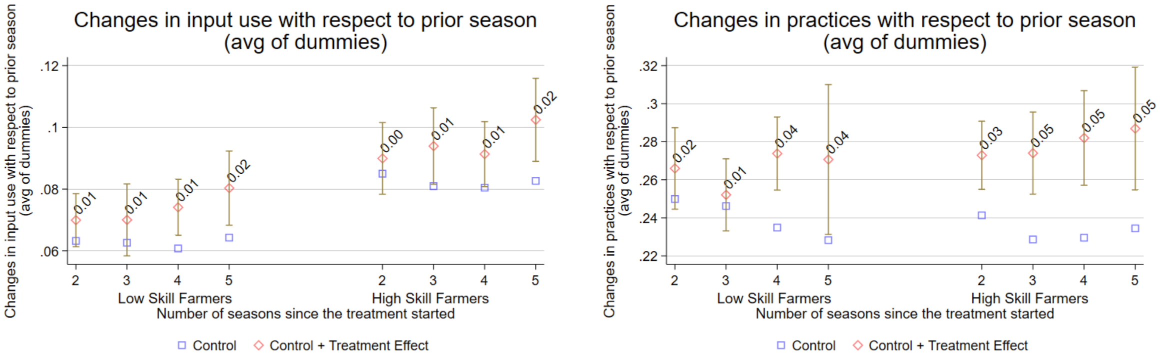
Are farmers decisions consistent with their trial yield increase?

VARIABLES	used any maize inputs of the trials (dummy)	used any soya inputs of the trials (dummy)
Maize yield increase in trial* LSF	-0.0145	
	(0.0575)	
Maize yield increase in trial* HSF	0.196***	
	(0.0485)	
Soya yield increase in trial* LSF		-0.00551
		(0.0375)
Soya yield increase in trial* HSF		0.0707**
		(0.0320)
Observations	1,412	1,141
Dep. var. mean	0.0880	0.0111
p-val LSF effect = HSF effect	0.0156	0.137

Experimentation: frequency of changes in practices and input use



- Significant increase in experimentation, not done by seasons 4 & 5
- HSFs experiment more and sooner

Subtle learning and complementarities

Subtle learning and mistakes

Table 1: Subtle learning and the effect of exposure to new information on potential mistakes

Concepts	Adapting inputs to conditions	Picking the best of 2 inputs	Proper combinations of inputs and practices			Wrong combinations of inputs and practices	
VARIABLES	WTP IR seeds if high striga minus low striga	WTP Sympal vs Minjingu	Used hybrid and one seed per hole	Used both commercial and homemade fertilizer on at least one plot	WTP Biofertilizer together with Sympal (N & P sources)	Used hybrid maize seed from own production	WTP Sympal and Mijingu (2 P sources together)
Treatment * LSF	0.098***	0	0.04	-0.047*	0.007	0.026	0.032***
	(0.022)	(0.023)	(0.026)	(0.026)	(0.008)	-0.016	(0.008)
Treatment * HSF	0.229***	0.077***	0.065**	-0.041	0.070***	0.040**	0.080***
	(0.034)	(0.029)	(0.032)	(0.025)	(0.015)	(0.018)	(0.012)
Observations	3,742	2,893	4,431	4,552	2,893	4,431	2,893
Avg outcome in LSF control grp	0.0534	0.0202	0.245	0.345	0.007	0.107	0.00119
Avg outcome in HSF control grp	0.174	0.0249	0.442	0.49	0.012	0.142	0.00262
P-val of Treat. (low & high sk.)	0	0.0478	0.0119	0.0139	0.0002	0.00198	0
P-val Treat. * LSF = Treat. * HSF	0.0007	0.0302	0.559	0.868	0.0000	0.587	0.0013

ADDITIONAL FINDINGS ON LEARNING FROM OTHERS

Cross-learning

- We use the exogenous variation about which crop treatment was assigned to each farmer in a village to see whether they learn from other treatments
- Substantial cross-learning occurs with regard to know-how
- But they only purchase the new inputs if they tried it themselves in the trials
- Cross learning becomes much more limited or inexistant for complex or subtle lessons
- The "influencers" are High Skill Farmers
- All farmers pay more attention to inut decisions and treatment status of HSFs (even LSFs)

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Conclusion and Policy Implications

- Multidimensionality of decisions, complementarities and site-specific recommendations are at the core of the learning challenges
- Respctful of the magnitude of the challenge faced by farmers when thinking of the "puzzle of non-adoption"
- This cost of adjusting other inputs and practices acts as an additional barrier to adoption
- Skills play an important role and can have a high externality.
- Particularly relevant for sustainable intensification and climate adaptation strategies: more knowledge intensive than capital intensive.
- Calls for combining top down knowledge with methods to increase local sharing of knowledge such as citizen science?