Signals, Similarity and Seeds: Social Learning in the Presence of Imperfect Information and Heterogeneity

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1. Introduction
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   - Context
2. Research design
   - Data sources
     - RCT
     - Network info
   - Variable definitions
   - Econometrics
3. Results
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   - Social network results
   - Heterogeneity

Learning & technology adoption

- Greater use of improved technologies could raise productivity and welfare in developing countries
- Returns are typically unknown and stochastic
- Understanding how individuals learn & decide what technologies to use crucial to boosting prosperity

Learning & technology adoption in agriculture

- Agricultural technologies provide a favorable and important context for the study of learning
- Farmers make production choices in an environment characterized by imperfections, where learning is difficult
  - financial imperfections: credit constraints and imperfect insurance markets
  - incomplete information about the availability and profitability of new technologies
  - complex and heterogeneous information environment
- Social learning plays a role in diffusion and adoption (Foster & Rosenzweig, 1995; Bandiera & Rasul, 2006; Conley & Udry, 2010; Magnan et al., 2013; Cai et al., 2014; Carter et al., 2014; Adhvaryu, 2014)

Agricultural productivity in SSA: low and stagnant

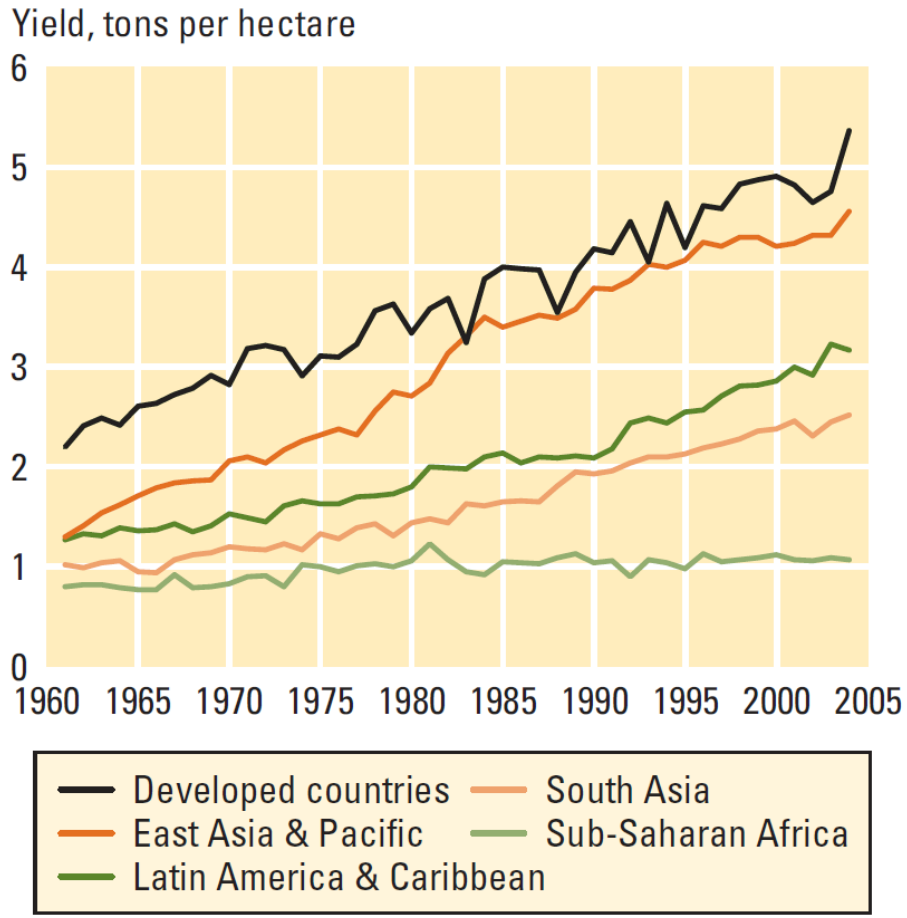

Figure : Cereal yields in SSA & other regions

Hybrids in Kenya

- Hybrid use is higher than many other SSA countries (40-70%)
- Stagnating maize production partly due to slow replacement of old hybrids
  - 2/3 of farmers grow a hybrid developed in 1986, suited for the Kenyan highlands (Tegemeo, 2010)
  - relevant decision is *type* of hybrid & this choice is complex
    - many seeds to choose from
    - soil quality varies widely

Farmers face substantial and growing complexity

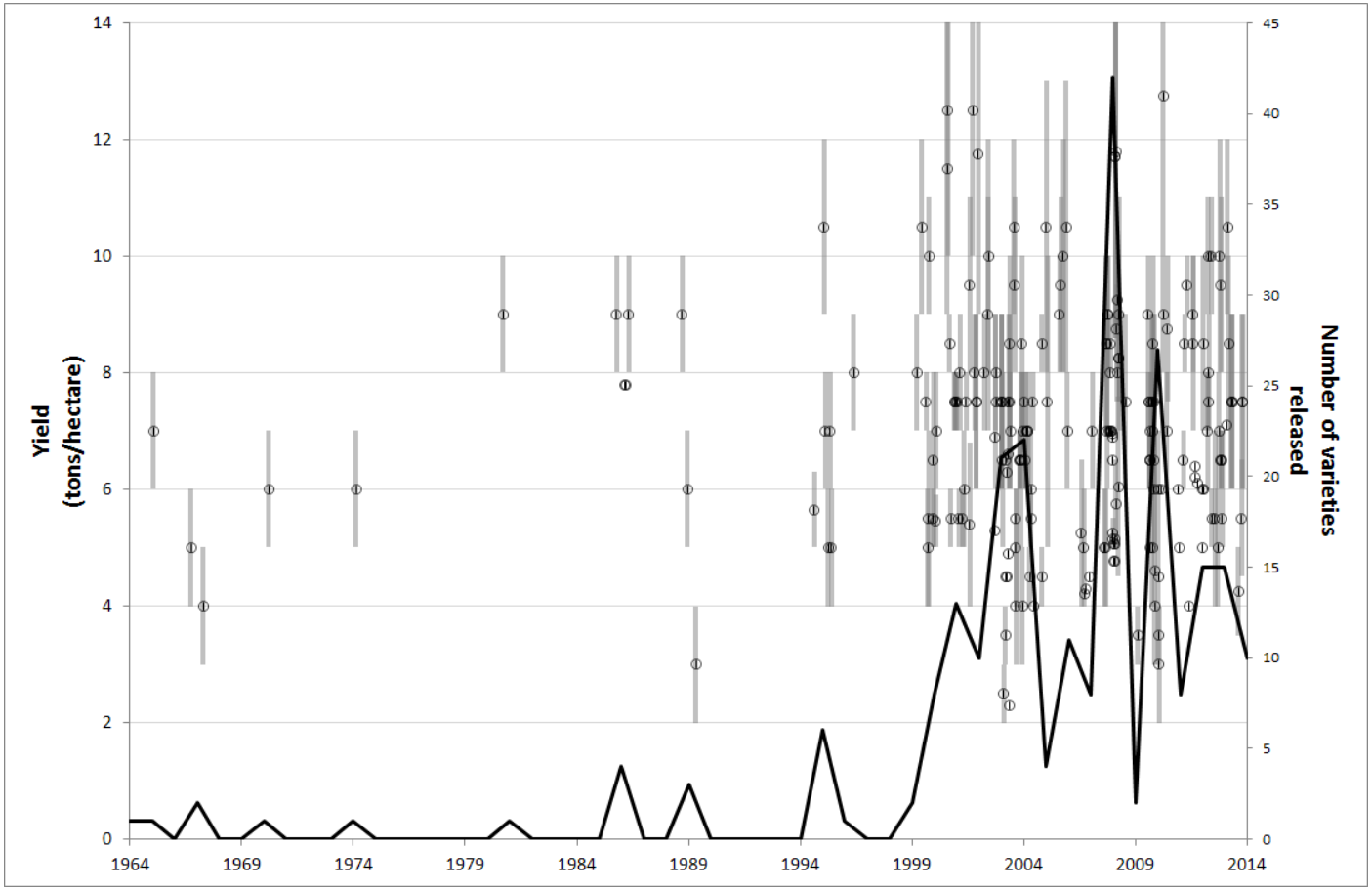

Figure : Number of maize varieties released in Kenya, 1964 - 2014 and their reported yield capacity

Region exhibits significant heterogeneity in soil quality

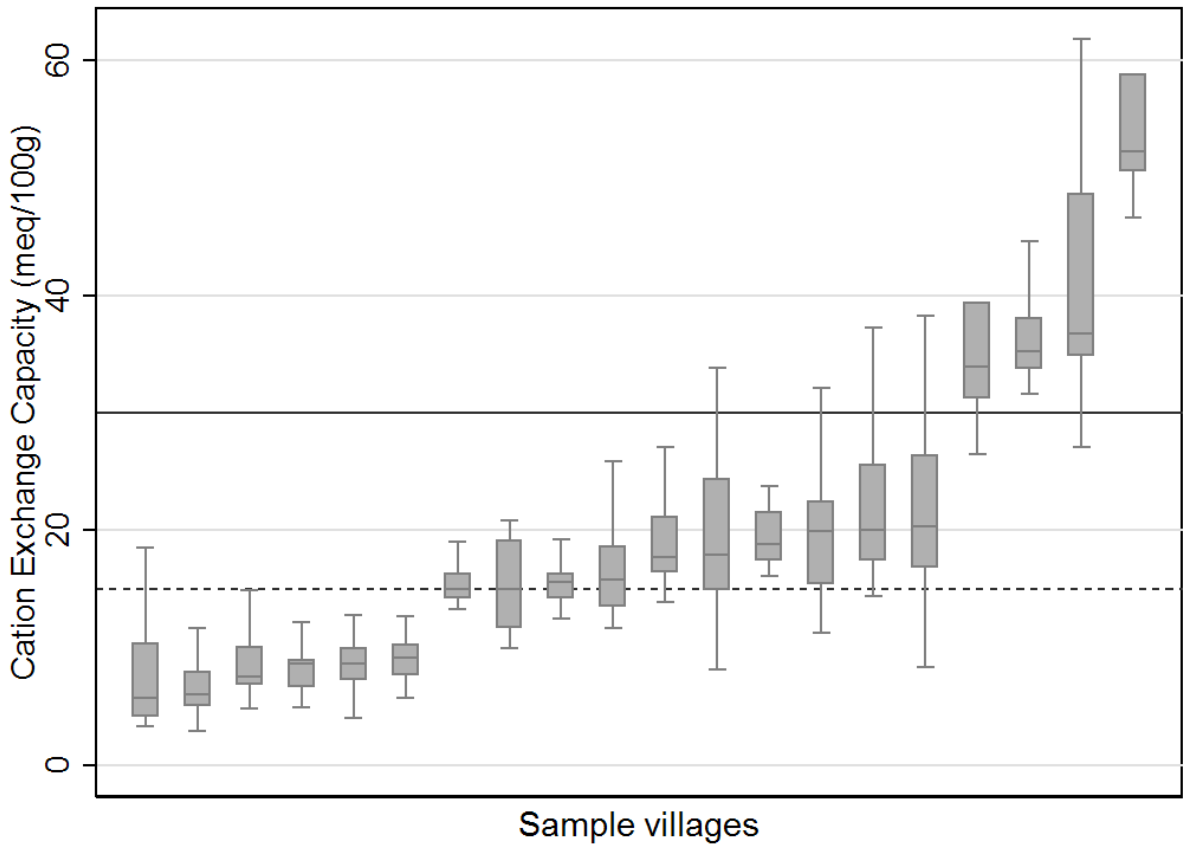

Figure : Box plot of Cation Exchange Capacity across sample villages

What I do & summary of results

- Experimental variation in information available to farmers about new tech
  - construct a measure of the signal in individuals' networks
  - examine how social networks affect familiarity, WTP and adoption of new tech
- Networks matter: they affect
  - familiarity
  - WTP
  - adoption
- Unobserved heterogeneity makes individuals less likely to respond to their peers' experiences

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  - familiarity
  - WTP
  - adoption
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Impact evaluation

- Large-scale RCT: *"Evaluating the socio-economic impacts of Western Seed's hybrid maize program"*
- Western Seed Company (WSC)
  - high-yielding maize hybrids
  - adapted to mid- & low- altitude areas
- Until recently, limited by capacity-constraints

Impact evaluation

- Study villages are in WSC expansion areas
  - no/little information or marketing
  - no/little access to the seeds
  - may have experience with other hybrids
- Cluster-randomized roll-out
  - information about WSC
  - 250g samples of the seeds
    - could plant small experimental plot
    - $\frac{1}{30}^{th}$ of average farmers land

Impact evaluation

- Villages divided into treatment and control clusters
- Sampled farmers in treatment villages received info & samples
- *Main goal:* induce different adoption levels between treatment and control villages
- *Experiment-within-experiment:* variation within treatment villages in the level of experience with the new technology
    - orthogonal to farmer attributes & social network characteristics

Farmer types

Farmer type	**Village**	**Info + sample**	**Baseline**	**Soil sample**	**Network**
Directly treated	Treatment	Yes	Yes	Yes	Yes
Indirectly treated	Treatment				Yes
Control	Control		Yes	Yes	

Farmer types

Farmer type	**Village**	**Info + sample**	**Baseline**	**Soil sample**	**Network**
Directly treated	Treatment	Yes	Yes	Yes	Yes
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Control	Control		Yes	Yes	

Impact evaluation - timeline

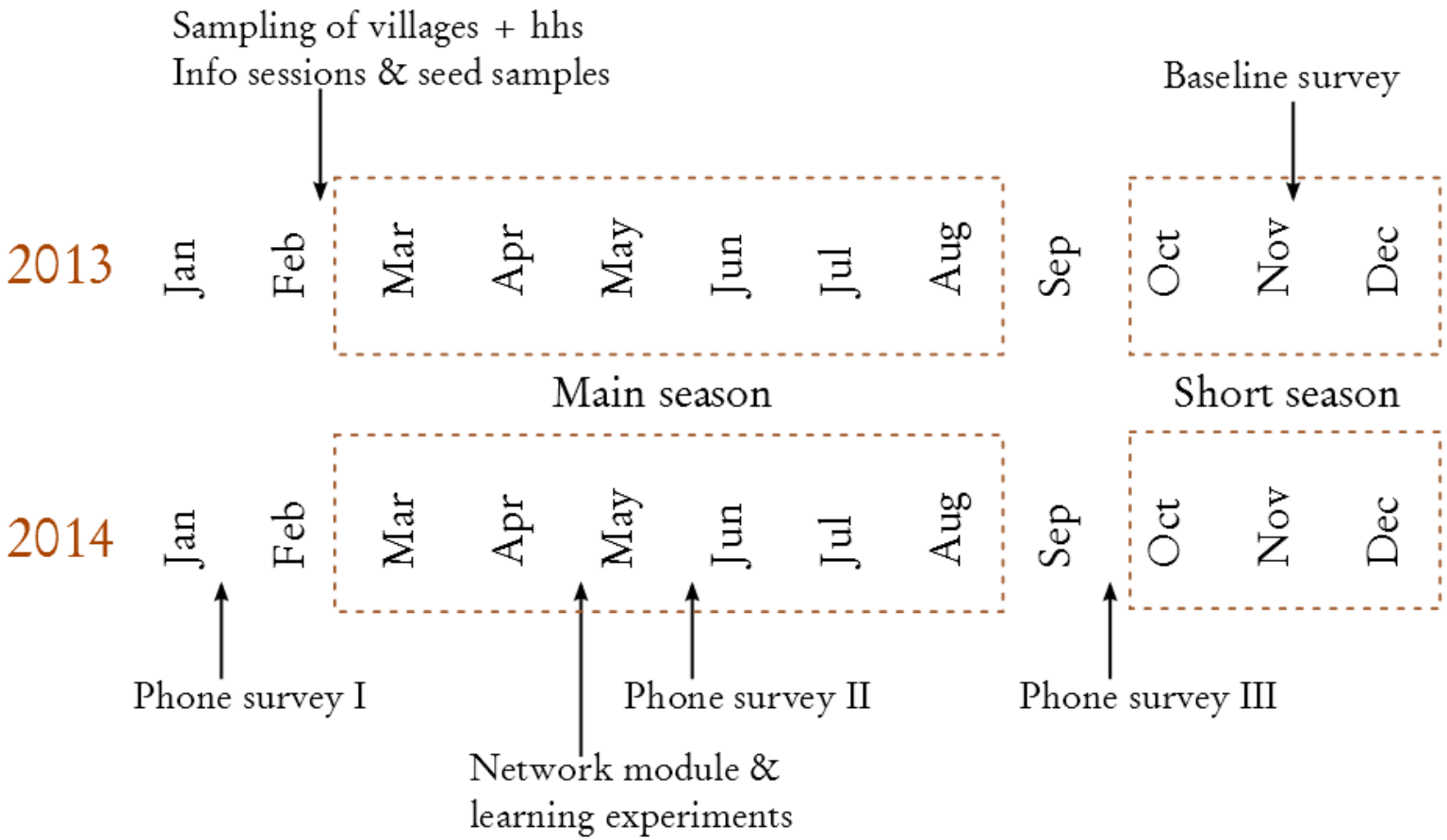
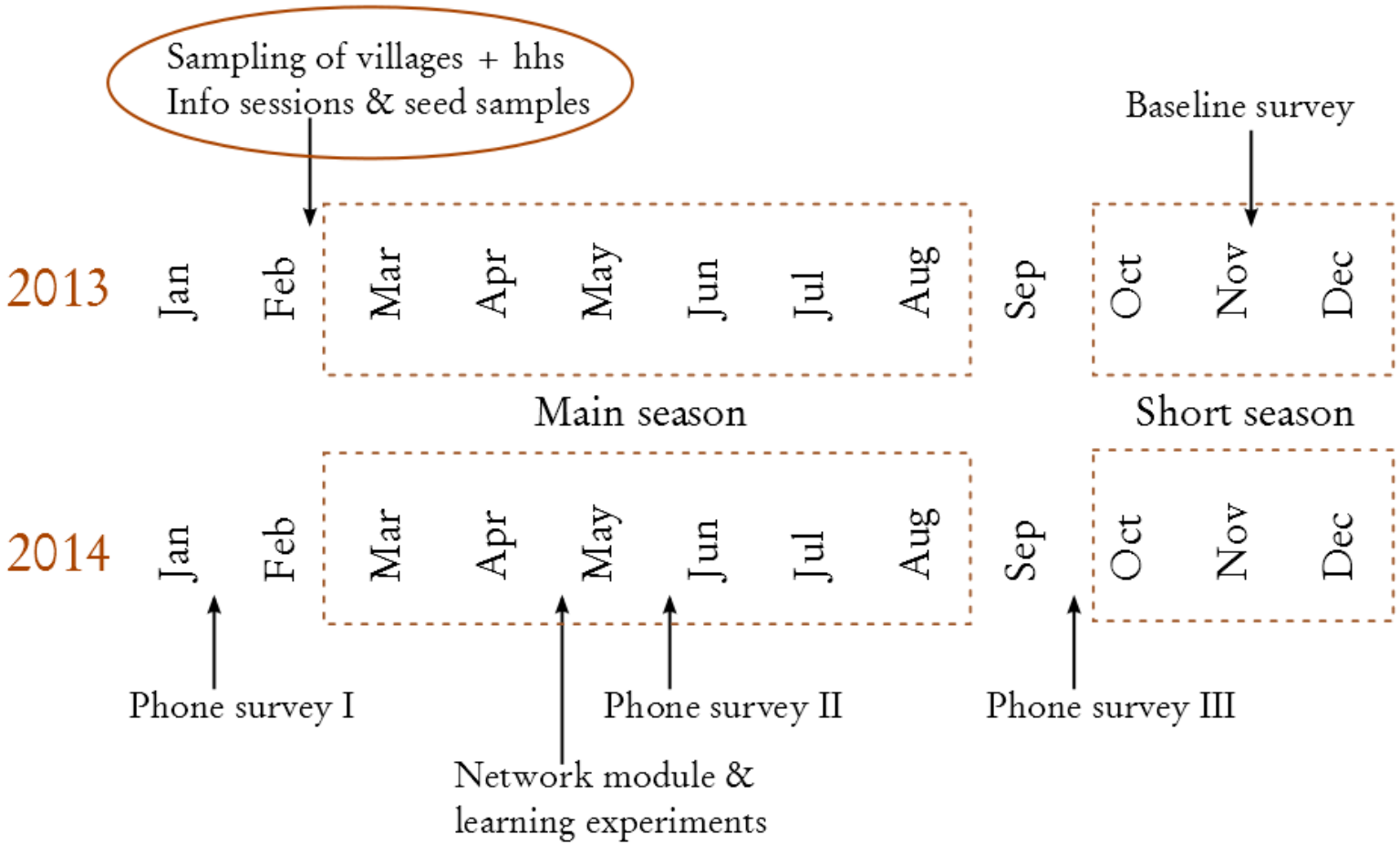


Figure : RCT timeline

Impact evaluation - timeline



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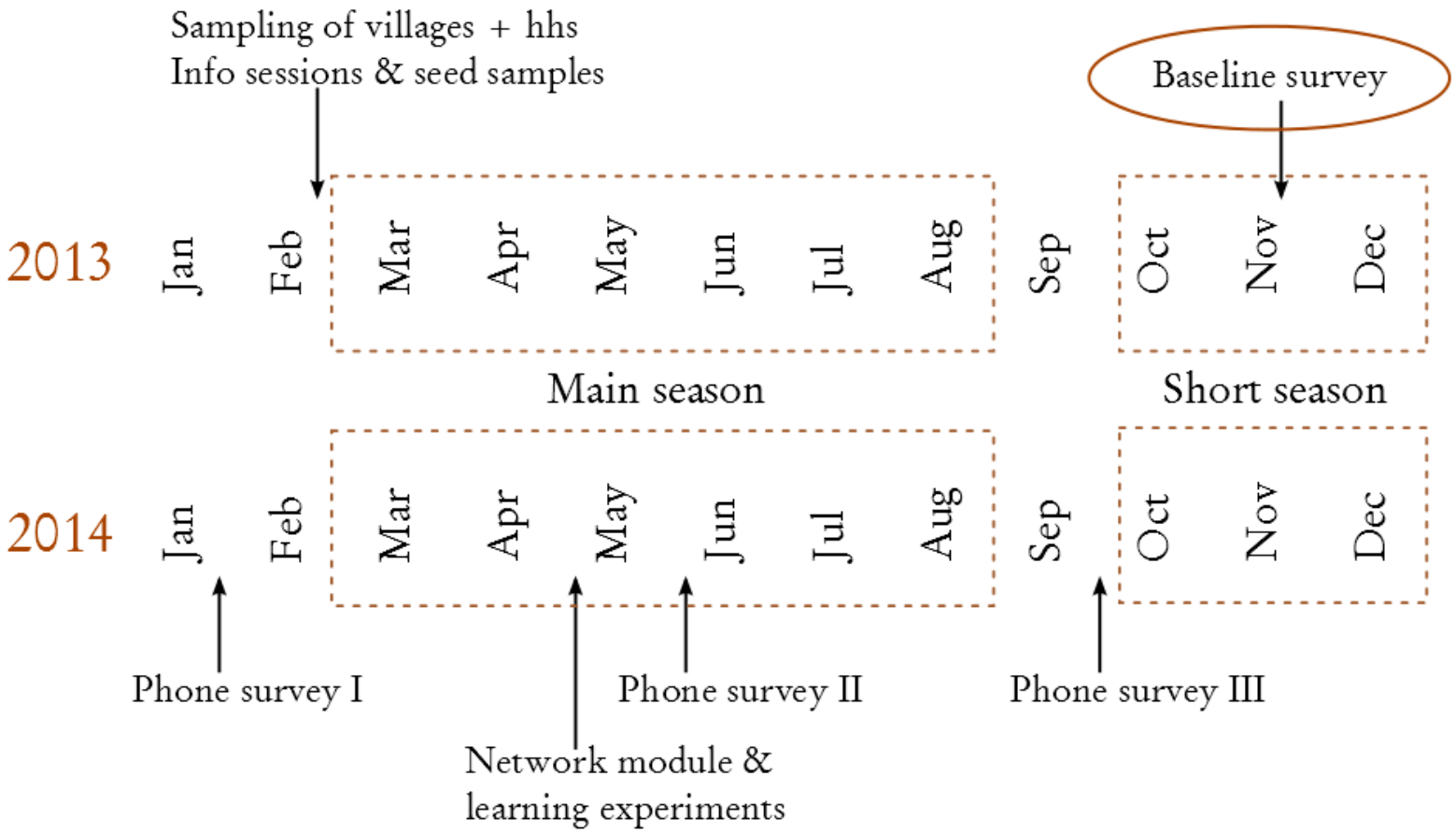
Impact evaluation - timeline



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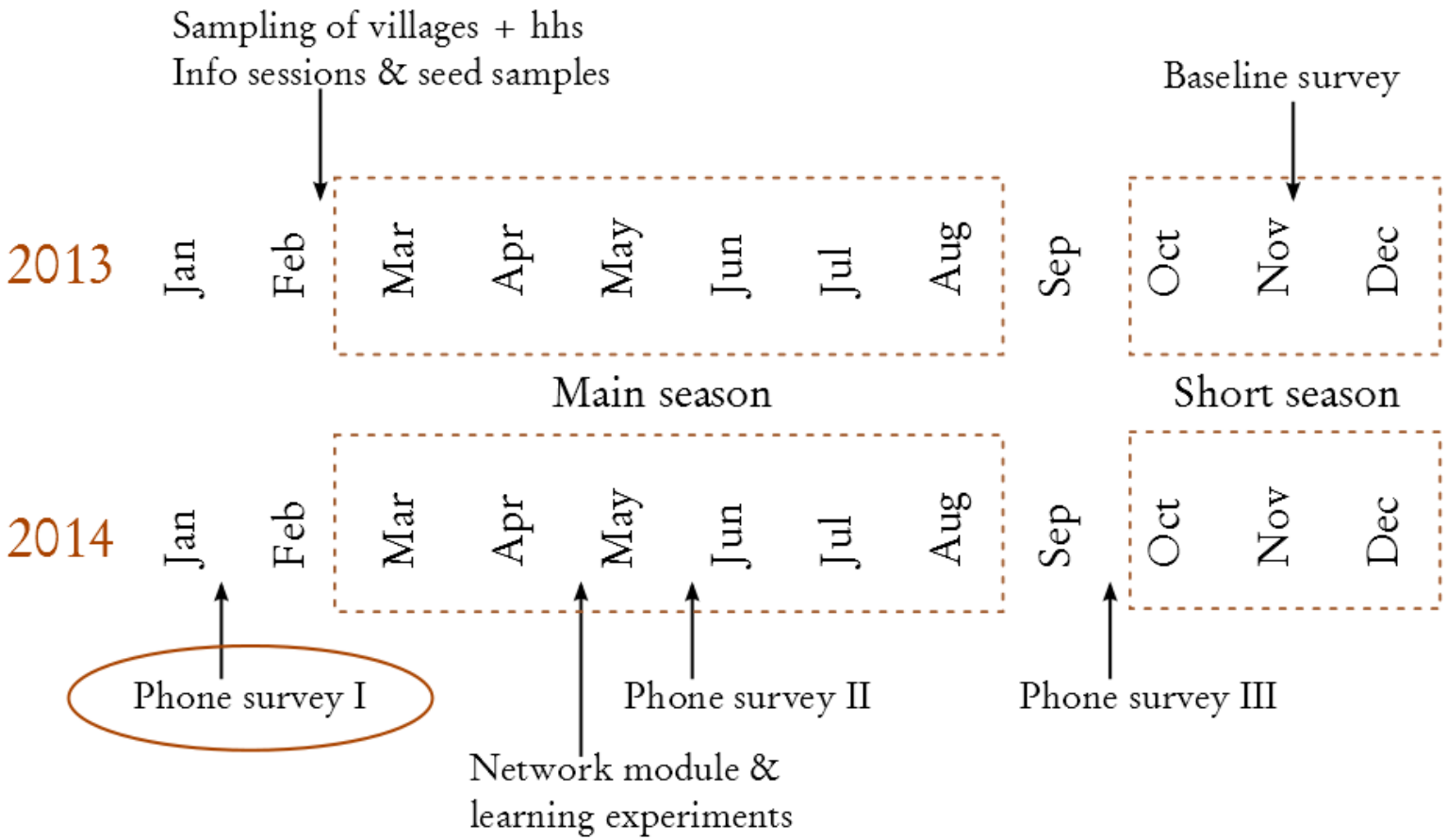


Figure : RCT timeline

Impact evaluation - timeline

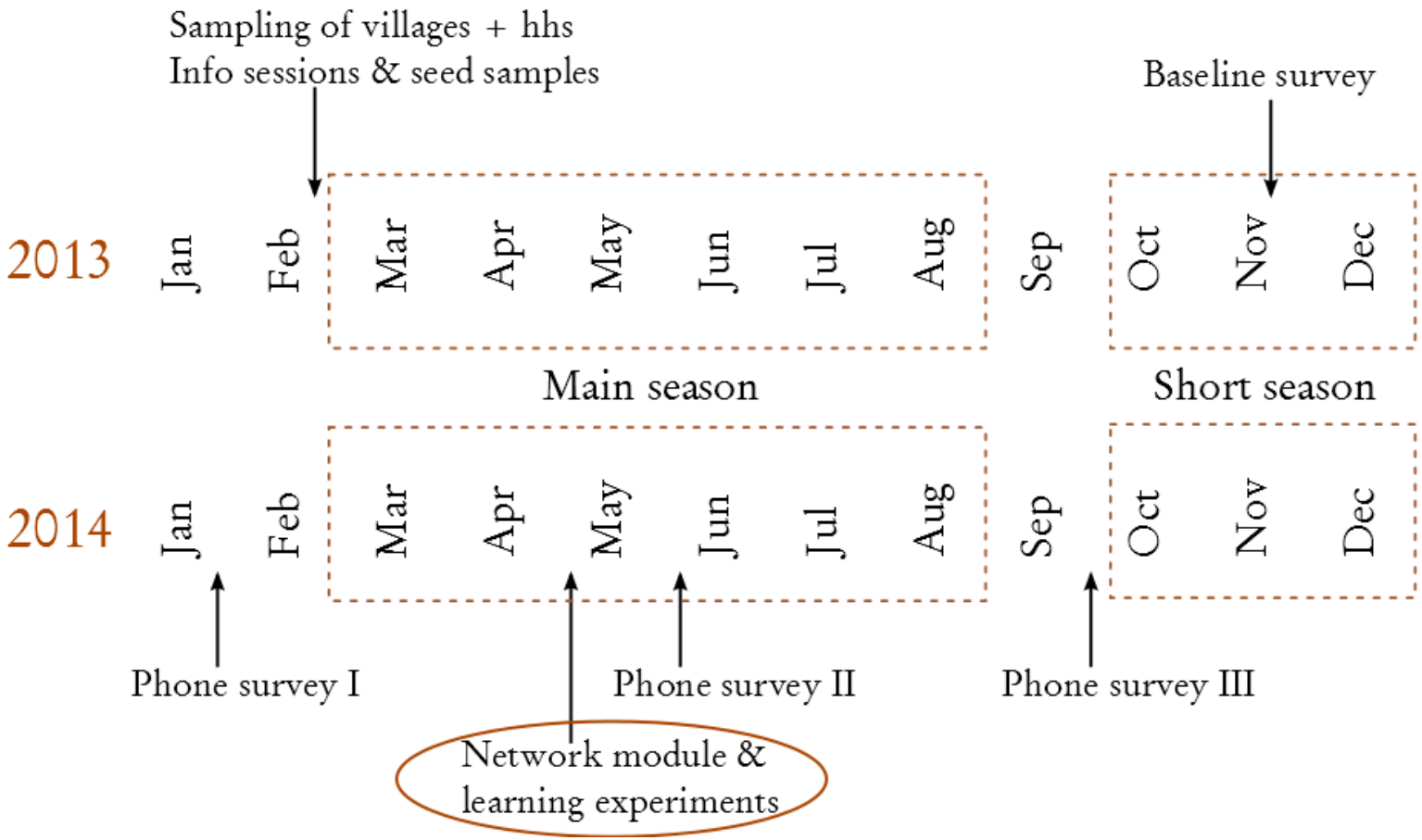


Figure : RCT timeline

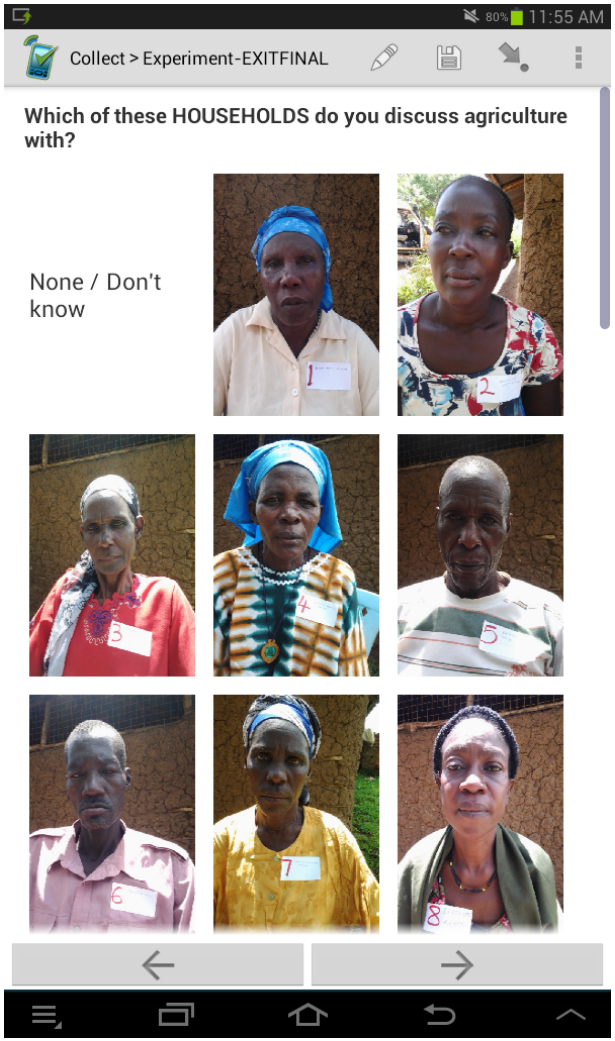
Network information

- Additional survey in 20 treatment villages
  - all directly treated hhs
  - random sample of indirectly treated
- 600 farmers invited; 575 (96%) showed up & participated
- Indirectly treated answered additional survey since not in baseline

Different network types

- Information neighbors
- Talk to (about anything, about ag + at different frequencies)
- Economic (microfinance, women's group, farming group)
- Geographic (walk/bike by, live closest to)
- Information (advice, what seeds they planted/prefer, most similar to you, recommend WSC hybrids)

Tablet network module



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Network definition

- For present analysis, individual *j* is in person *i*'s social network if person *i* listed them in *any* of the network questions
- Many options for defining information networks
  - *reciprocal*: *i* mentions *j* and *j* mentions *i*
  - *corrected*: remove those who spoke about maize for the first time after treatment

Network definition

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Information signal

- Several recent papers use experimental variation in networks (Carter et al., 2014; Cai et al., 2014; Magnan et al., 2013; Oster & Thornton, 2012)
- Unlike earlier observational studies that used innovative measures of information, the experimental studies rely on number of treated in network
  - gets around reflection problem (Manski, 1993)
  - implicitly assumes 'social influence' model, rather than social *learning*

Information signal

- Phone survey with treated - elicit their experience with the technology

1. Actual experience (y_i): "How much did you harvest from the sample pack seeds?"
2. Subjective counterfactual ($\tilde{y}_i$): "How much would you have harvested (same weather, input use, etc) if you had planted the seeds you normally grow instead of WSC hybrids?"

- Denote the perceived experimental gains by Δ_i

$$\Delta_i = \frac{y_i - \tilde{y}_i}{\tilde{y}_i}$$

Information signal

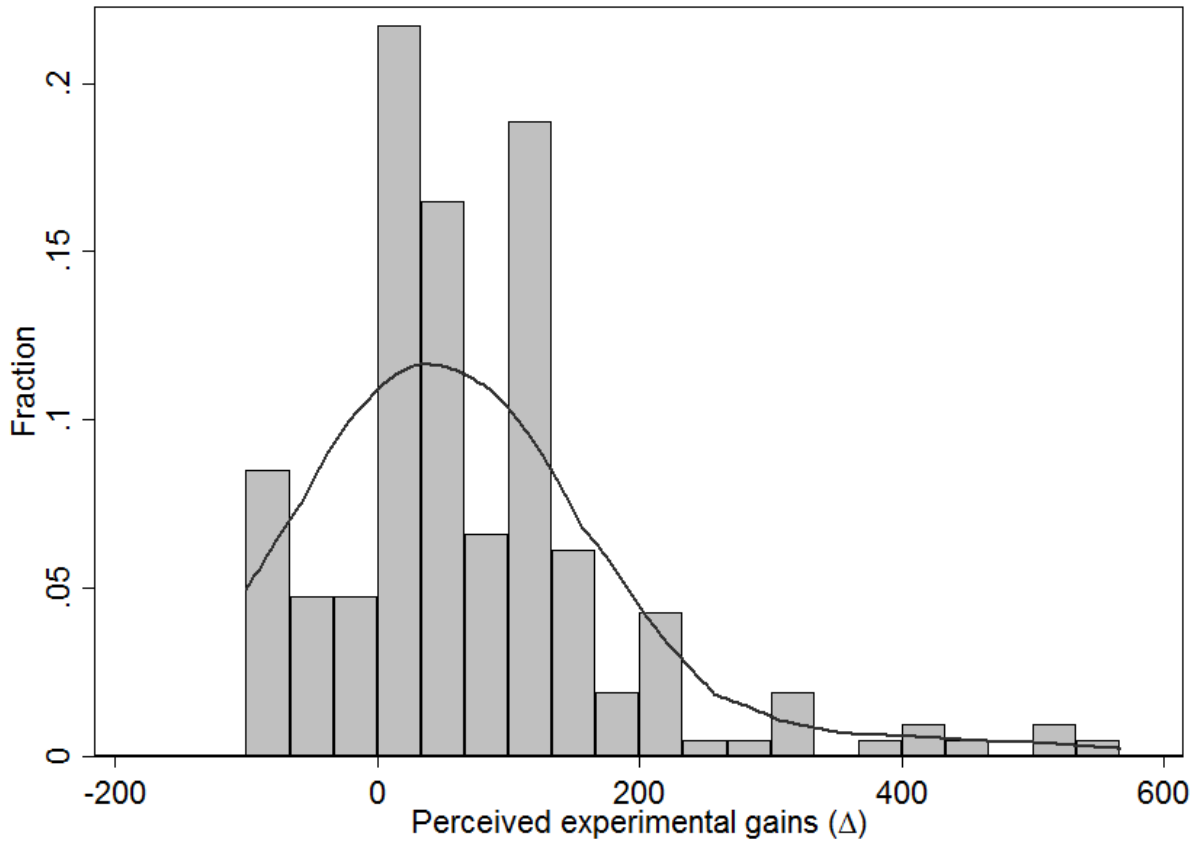

Figure : Distribution of treated farmers' evaluation of the performance of the hybrid seed samples

Information signal

- The experiences of the farmers in person i's network combine to form a distribution of signals from which she can learn
  - compute the mean and variance of the signals in a respondent's network

$$\mu_i = \sum_{j \in N_i} \frac{\Delta_j}{N_i}$$

$$\sigma_i = \sum_{j \in N_i} \frac{(\Delta_j - \mu_i)^2}{N_i}$$

- A higher μ_i should increase likelihood that farmer i adopts
- A higher σ_i, i.e. a noisier signal, should decrease farmer i's response to the signal

Information signal

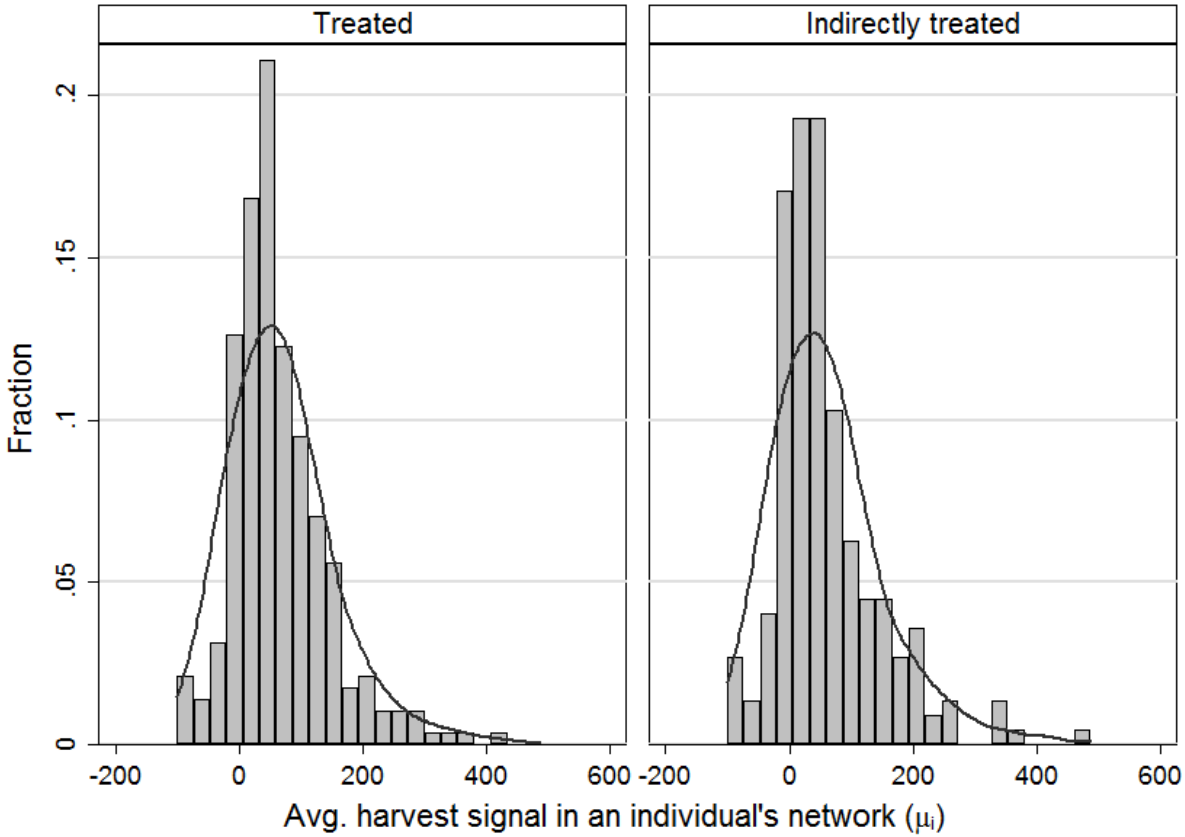

Figure : Distribution of μ_i

Outcome variables

- Familiarity with WSC hybrids
- WTP for WSC hybrids
- Planted a WSC variety
- Planted a non-WSC variety

Familiarity with WSC hybrids

- Indicator variable equal to 1 if respondent is familiar with the technology
- 1^{st} stage of WTP module:
  - respondents shown cards with names of ca. 20 seed varieties
  - asked whether they feel they know enough about the varieties to decide whether or not they would like to plant them
- Measures whether respondent has enough knowledge about WSC hybrid to compare the tech to other seeds?
- Intuitively, have to be familiar with the seed before adopting
  - more restrictive than 'have you heard of WSC hybrids?'

Price-premium based WTP

- 2^{nd} stage of WTP module:
  - rank the seeds with which familiar
- 3^{rd}stage:
  - if ranked a WSC variety over another hybrid, elicited premium
  - add premium to the price of the other hybrid
- Could pick up learning if adoption impacts are limited by liquidity constraints and/or other market imperfections
- Not everyone answers the WTP module

Actual planting behavior

- Planted a WSC variety (0/1)
  - more stringent measure of adoption than other experimental network papers
    - Bandiera & Rasul, 2006; Cai et al, 2014; Oster & Thornton, 2012; Miguel & Kremer, 2004
- Planted a non-WSC hybrid
  - could be 0, positive or negative depending on previous hybrid use and/or spillovers

General specification

$$y_{iv} = f(N_{iv}) + \gamma \mathbf{X}_i + \varepsilon_{iv}$$

- y_{iv} is outcome for household i in village v
- $\mathbf{X}_i$ is vector of baseline control variables
- $f(N_{iv})$ function of information in individual i's network
- s.e.'s clustered at village level

General specification

$$y_{iv} = f(N_{iv}) + \gamma \mathbf{X}_i + \varepsilon_{iv}$$

- N_{iv} represents either
  1. number of treated farmers in farmer i's network
  2. first two moments of distribution of experiences reported by treated individuals in her network
- Recent experimental studies typically only consider 1)

General specification

- These "social influence" models include the number of treated in network in different forms
  - # of treated (Babcock & Hartman, 2010; Oster & Thornton, 2012)
  - share of treated (Cai et al., 2014)
  - indicator vars for having 1,2, 3... treated members (Carter et al., 2014)
  - dummy for having *any* treated network members (Magnan et al., 2013)
- I use dummies for 1 and "2 or more" treated network members

Social networks model

- 'Social influence' model:

$$y_{iv} = \alpha_1 + \beta_k \sum_{k=1}^{K} I_{iv}^k + \gamma_1 \mathbf{X}_i + \varepsilon_{iv}$$

where K in our preferred model is 2+

- Information signal model:

$$y_{iv} = \alpha_2 + \lambda_k \sum_{k=1}^{2} m_{iv}^k + \gamma_2 \mathbf{X}_i + \nu_{iv}$$

m_i^k denotes the k^{th} moment of the distribution of signals in person i's network

Social networks model

- Estimate most models using OLS
- When outcome variable is WTP for technology, use Tobit as it might be censored at 0

Social networks model

- Controls include
  - proxies for prior experience with improved tech:
    - dummy for being in a village where the majority of treated do *not* know where to purchase
    - dummy for having used hybrids & fertilizer
  - household characteristics:
    - size of main maize field
    - risk attitudes
    - understanding score from experiments
    - PPI score
    - microfinance participation
  - network controls:
    - total network size; signal-regressions also dummies for number of treated links

Heterogeneity

- Cation Exchange Capacity (CEC): summary statistic of soil quality
  - often used to gauge soil fertility
  - varies in sample villages & the *extent* of variation also varies between villages
- Compute the coefficient of variation (CV) of CEC: measure of unobserved heterogeneity
- Interact CV_{CEC} with social network variables

Summary statistics

Variable	mean	sd	min	max	mean(T) - mean(I)	*t*-stat
Household characteristics						
Kiswahili spoken at home	0.03	0.18	0	1	-0.001	(-0.06)
Luhya spoken at home	0.19	0.39	0	1	0.045	(1.41)
Luo spoken at home	0.78	0.42	0	1	-0.045	(-1.29)
In womens' or farm group	0.48	0.50	0	1	0.076*	(1.83)
In microfinance group	0.25	0.43	0	1	0.009	(0.25)
General risk taking attitude (0-10)	8.15	2.04	0	10	0.081	(0.47)
Understanding score, exp. games	0.74	0.34	0	1	-0.024	(-0.85)
PPI score (0-100)	44.49	12.41	14	84	1.409	(1.35)

t statistics in parentheses, standard errors clustered at the village level
* p<.1, ** p<.05, *** p<.01

Table : Summary statistics

Summary statistics

Variable	mean	sd	min	max	mean(T) - mean(I)	*t*-stat
Agricultural characteristics						
Size of main maize field (acres)	1.30	1.16	.07	10	0.201**	(2.16)
Nr. of seasons used fertilizer, 4 years	2.57	3.33	0	8	0.479*	(1.71)
Nr. of seasons used hybrids, 4 years	3.32	3.33	0	8	-0.059	(-0.21)
Network characteristics						
Nr. of relatives	2.43	2.23	0	12	0.070	(0.38)
Nr. of treated relatives	1.31	1.39	0	8	0.080	(0.69)
Nr. of links (all)	7.05	3.92	0	29	0.344	(1.08)
Nr. of treated links (all)	4.08	2.51	0	20	0.549***	(2.69)
Nr. of reciprocal links (all)	3.29	2.50	0	22	0.409**	(2.01)
Nr. of treated reciprocal links (all)	1.93	1.71	0	15	0.435***	(3.15)
Nr. of links in corrected network	6.73	3.78	0	29	0.154	(0.50)
Nr. of treated links, corrected network	3.85	2.41	0	19	0.400**	(2.03)

t statistics in parentheses, standard errors clustered at the village level
* p<.1, ** p<.05, *** p<.01

Balance on observables

- Require that treatment induced exogenous variation in number of treated network members in a given individual's network
  - conditional on individual *i*'s total number of links (total network size), the number of *treated* links was randomized
  - test the validity this assumption by regressing baseline characteristics on number of treated links (controlling for total network size)
- Do this separately for treated & indirectly treated
- Test using 3 different network definitions

Balance on observables

Variable	Coeff. on nr. of treated links, controlling for nr. of links			
	Relatives		Corrected	
	T	I	T	I
Household characteristics				
In womens' or farm group	-0.009 (-0.20)	0.008 (0.23)	-0.012 (-0.59)	0.024 (1.21)
In microfinance group	-0.047* (-1.90)	-0.002 (-0.07)	-0.013 (-0.89)	0.040*** (3.57)
General risk taking perception (0-10)	-0.089 (-0.50)	0.018 (0.12)	-0.061 (-1.03)	-0.033 (-0.34)
Understanding score, exp. games	-0.010 (-0.42)	0.035 (1.33)	-0.012 (-1.16)	0.017 (0.88)
Sum of core 10 PPI scores (0-100)	-0.506 (-0.68)	1.248 (1.09)	-0.354 (-0.52)	0.655 (1.02)

t statistics in parentheses, standard errors clustered at the village level

* p<.1, ** p<.05, *** p<.01

Table : Regression of baseline vars on nr. of treated links

Balance on observables

Variable	Coeff. on nr. of treated links, controlling for nr. of links			
	Relatives		Corrected	
	T	I	T	I
Agricultural characteristics				
Size of main maize field (acres)	-0.026 (-0.27)	0.024 (0.35)	-0.029 (-0.55)	-0.038 (-0.69)
Nr. of seasons used fertilizer, 4 years	0.440 (1.37)	0.271 (1.07)	0.303 (1.56)	0.536*** (3.21)
Nr. of seasons used hybrids, 4 years	0.334 (1.26)	0.882*** (2.92)	0.244 (1.32)	0.628*** (3.88)

t statistics in parentheses, standard errors clustered at the village level

* p<.1, ** p<.05, *** p<.01

Table : Regression of baseline vars on nr. of treated links

Familiarity, social influence model

(Dep. variable: Familiar with WSC hybrid?)

Panel A -	**Treated**			**Indirectly treated**	
Nr. of treated links	1	2	3	4	5
1 treated link	0.20 (0.2)	0.097 (0.3)	0.29 (0.3)	0.020 (0.1)	0.53*** (0.2)
2+ treated links	0.31 (0.2)	0.50* (0.3)	0.47* (0.3)	0.082 (0.2)	0.36** (0.2)
Network size	0.0071 (0.006)	0.13 (0.1)	0.0042 (0.007)	0.013 (0.01)	0.19*** (0.06)
(1 treated)*(nw. size)		-0.036 (0.1)			-0.23*** (0.07)
(2+ treated)*(nw. size)		-0.12 (0.1)			-0.18** (0.06)
On-farm trial outcome			0.00067 (0.03)		
(On-farm trial outcome)^2			0.00016 (0.002)		
Additional covars	YES	YES	YES	YES	YES
Observations	319	319	217	255	255
Adjusted R^2	0.078	0.083	0.087	0.229	0.237

In both panels: standard errors in parentheses;
s.e.'s clustered at the village level; * p<.1, ** p<.05, *** p<.01
Network definition used: individual *j* is in person *i*'s network
if person *i* listed them in *any* of the network questions.

Table : Social network effects on farmer familiarity with WSC hybrids

Familiarity, information signal model

(Dep. variable: Familiar with WSC hybrid?)

	Treated		**Indirectly treated**
Panel B - Signal in nw	1	2	3
Avg. signal in nw.	0.022	-0.027	0.00024
	(0.03)	(0.04)	(0.01)
Variance of signal in nw.	-0.0000016	0.0022	-0.0046***
	(0.002)	(0.002)	(0.0010)
Network size	0.0066	0.0019	0.014
	(0.006)	(0.007)	(0.01)
On-farm trial outcome		0.0073	
		(0.03)	
(On-farm trial outcome)^2		-0.00017	
		(0.002)	
Additional covars	YES	YES	YES
Observations	294	202	227
Adjusted R^2	0.042	0.006	0.238

In both panels: standard errors in parentheses;
s.e.'s clustered at the village level; * p<.1, ** p<.05, *** p<.01
Network definition used: individual *j* is in person *i*'s network
if person *i* listed them in *any* of the network questions.

Table : Social network effects on farmer familiarity with WSC hybrids

WTP, social influence model

(Dep. variable: Willingness to pay for WSC hybrid)

Panel A -	**Treated**		**Indirectly treated**
Nr. of treated links	1	2	3
1 treated link	83.0 (77.0)	84.1 (126.7)	314.9*** (73.9)
2+ treated links	116.8** (51.7)	96.1 (108.9)	263.0*** (66.2)
Network size	2.40 (3.8)	4.13 (4.5)	9.49 (9.3)
On-farm trial outcome		26.6 (18.1)	
(On-farm trial outcome)^2		-1.80 (1.1)	
Additional covars	YES	YES	YES
Observations	224	173	96
Adjusted R^2	0.064	0.087	0.075

In both panels: standard errors in parentheses;
s.e.'s clustered at the village level; * p<.1, ** p<.05, *** p<.01
Network definition used: individual *j* is in person *i*'s network
if person *i* listed them in *any* of the network questions.

Table : Social network effects on farmer WTP for WSC hybrids

WTP, information signal model

(Dep. variable: Willingness to pay for WSC hybrid)

Tobit regression	**Treated**		**Indirectly treated**
Panel B - Signal in nw	1	2	3
Avg. signal in nw.	31.0**	25.6	109.0***
	(14.2)	(16.7)	(19.8)
Variance of signal in nw.	-1.55**	-1.03	-17.5***
	(0.8)	(0.9)	(6.1)
Network size	3.92	5.78	14.0
	(4.2)	(5.1)	(8.6)
On-farm trial outcome		30.9	
		(21.8)	
(On-farm trial outcome)^2		-2.04	
		(1.4)	
Additional covars	YES	YES	YES
Observations	215	168	92
σ	227.2***	223.4***	217.5***

In both panels: standard errors in parentheses;
s.e.'s clustered at the village level; * p<.1, ** p<.05, *** p<.01
Network definition used: individual *j* is in person *i*'s network
if person *i* listed them in *any* of the network questions.

WSC hybrid adoption, social influence model

(Dep. variable: Planted WSC hybrid?)

Panel A -	**Treated**		**Indirectly treated**
Nr. of treated links	1	2	3
1 treated link	0.35***	0.32***	-0.012
	(0.08)	(0.08)	(0.04)
2+ treated links	0.13**	0.16*	0.029
	(0.06)	(0.08)	(0.03)
Network size	0.0066	0.0051	0.0023
	(0.006)	(0.006)	(0.005)
On-farm trial outcome		0.039	
		(0.02)	
(On-farm trial outcome)^2		-0.0029*	
		(0.001)	
Additional covars	YES	YES	YES
Observations	319	217	255
Adjusted R^2	0.083	0.073	0.045

In both panels: standard errors in parentheses;
s.e.'s clustered at the village level; * p<.1, ** p<.05, *** p<.01
Network definition used: individual *j* is in person *i*'s network
if person *i* listed them in *any* of the network questions.

Table : Social network effects on probability of planting a WSC hybrid

WSC hybrid adoption, information signal model

(Dep. variable: Planted WSC hybrid?)

	Treated		**Indirectly treated**
Panel B - Signal in nw	1	2	3
Avg. signal in nw.	-0.023	-0.032	-0.00015
	(0.02)	(0.03)	(0.005)
Variance of signal in nw.	0.0034	0.0044**	0.0012
	(0.002)	(0.002)	(0.002)
Network size	0.0065	0.0048	0.0041
	(0.006)	(0.006)	(0.005)
On-farm trial outcome		0.042	
		(0.03)	
(On-farm trial outcome)^2		-0.0029*	
		(0.001)	
Additional covars	YES	YES	YES
Observations	294	202	227
Adjusted R^2	0.088	0.072	0.035

In both panels: standard errors in parentheses;
s.e.'s clustered at the village level; * p<.1, ** p<.05, *** p<.01
Network definition used: individual *j* is in person *i*'s network
if person *i* listed them in *any* of the network questions.

Planted other hybrid, social influence model

(Dep. variable: Planted a non-WSC hybrid?)

Panel A -	**Treated**		**Indirectly treated**
Nr. of treated links	1	2	3
1 treated link	-0.35*	-0.21	0.0079
	(0.2)	(0.2)	(0.2)
2+ treated links	-0.19	-0.14	-0.013
	(0.1)	(0.1)	(0.2)
Network size	0.0080	0.013	-0.0024
	(0.007)	(0.008)	(0.010)
On-farm trial outcome		0.074**	
		(0.03)	
(On-farm trial outcome)^2		-0.0034	
		(0.002)	
Additional covars	YES	YES	YES
Observations	319	217	255
Adjusted R^2	0.166	0.128	0.276

In both panels: standard errors in parentheses;
s.e.'s clustered at the village level; * p<.1, ** p<.05, *** p<.01
Network definition used: individual *j* is in person *i*'s network
if person *i* listed them in *any* of the network questions.

Table : Social network effects on probability of planting a non-WSC hybrid

Planted other hybrid, information signal model

(Dep. variable: Planted a non-WSC hybrid?)

	Treated		**Indirectly treated**
Panel B - Signal in nw	1	2	3
Avg. signal in nw.	0.027	0.021	0.0062
	(0.03)	(0.04)	(0.01)
Variance of signal in nw.	-0.0040*	-0.0037*	-0.0089***
	(0.002)	(0.002)	(0.003)
Network size	0.0089	0.012	-0.0016
	(0.008)	(0.008)	(0.01)
On-farm trial outcome		0.077**	
		(0.03)	
(On-farm trial outcome)^2		-0.0035	
		(0.002)	
Additional covars	YES	YES	YES
Observations	294	202	227
Adjusted R^2	0.170	0.110	0.311

In both panels: standard errors in parentheses;
s.e.'s clustered at the village level; * p<.1, ** p<.05, *** p<.01
Network definition used: individual *j* is in person *i*'s network
if person *i* listed them in *any* of the network questions.

Familiarity

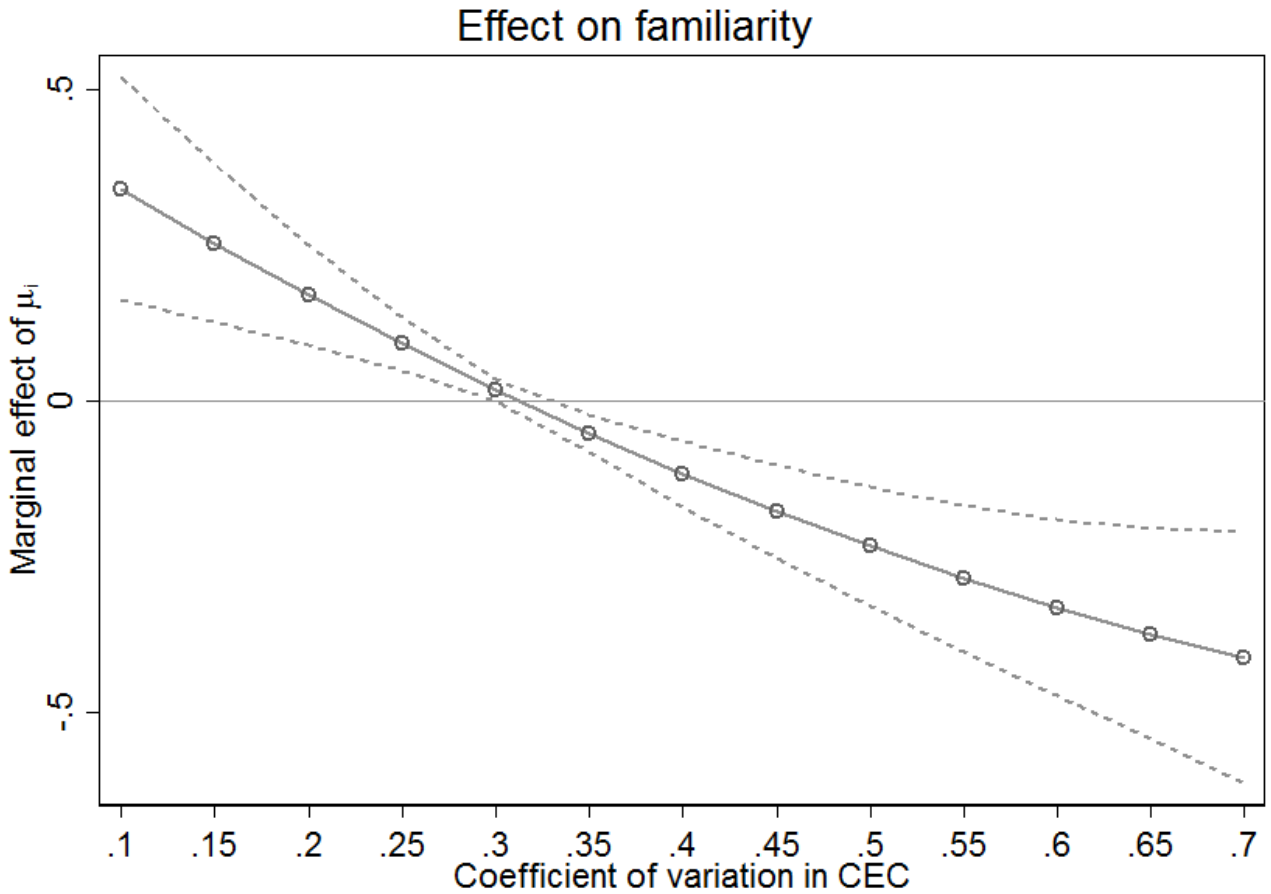

Figure : How impact of avg. signal in nw. varies with heterogeneity

WTP

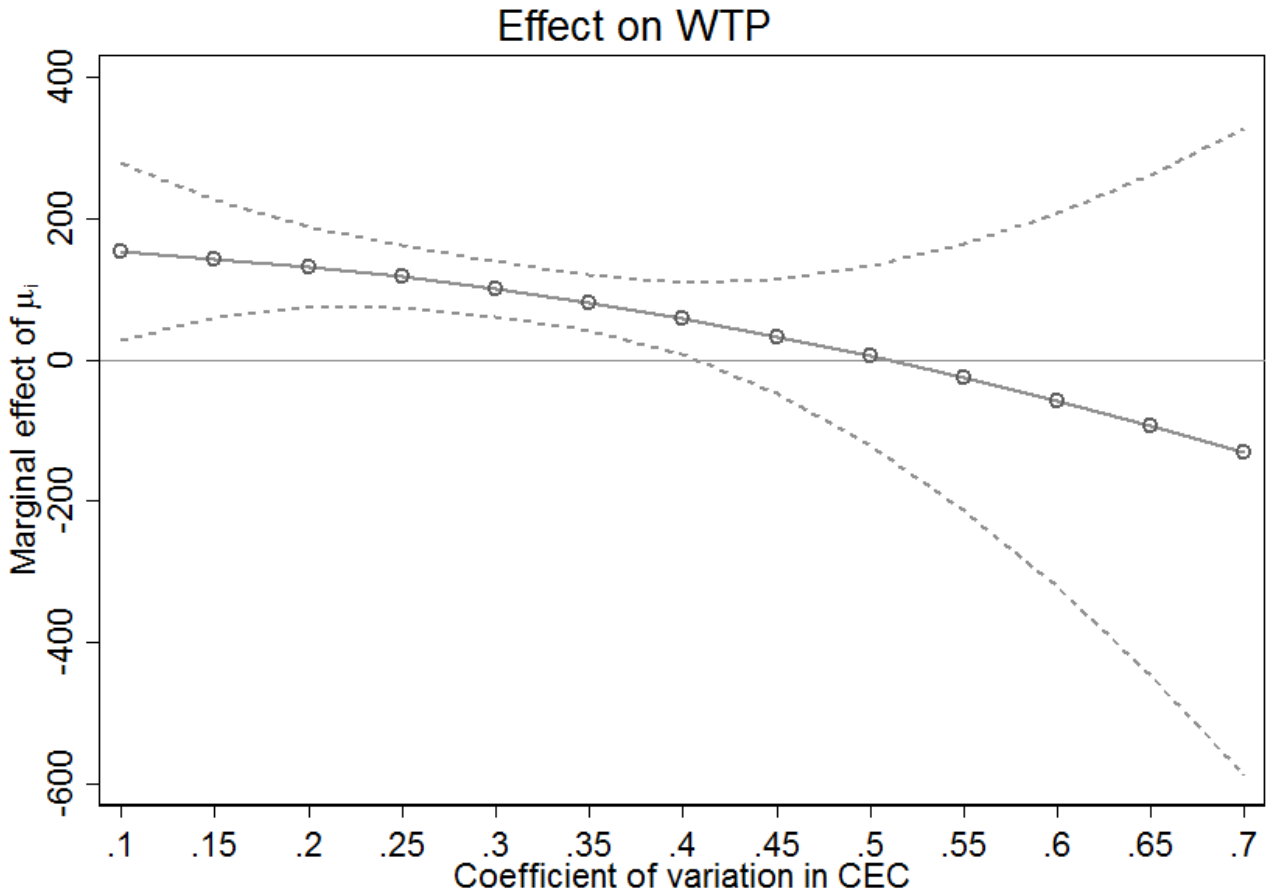

Figure : How impact of avg. signal in nw. varies with heterogeneity

WSC adoption

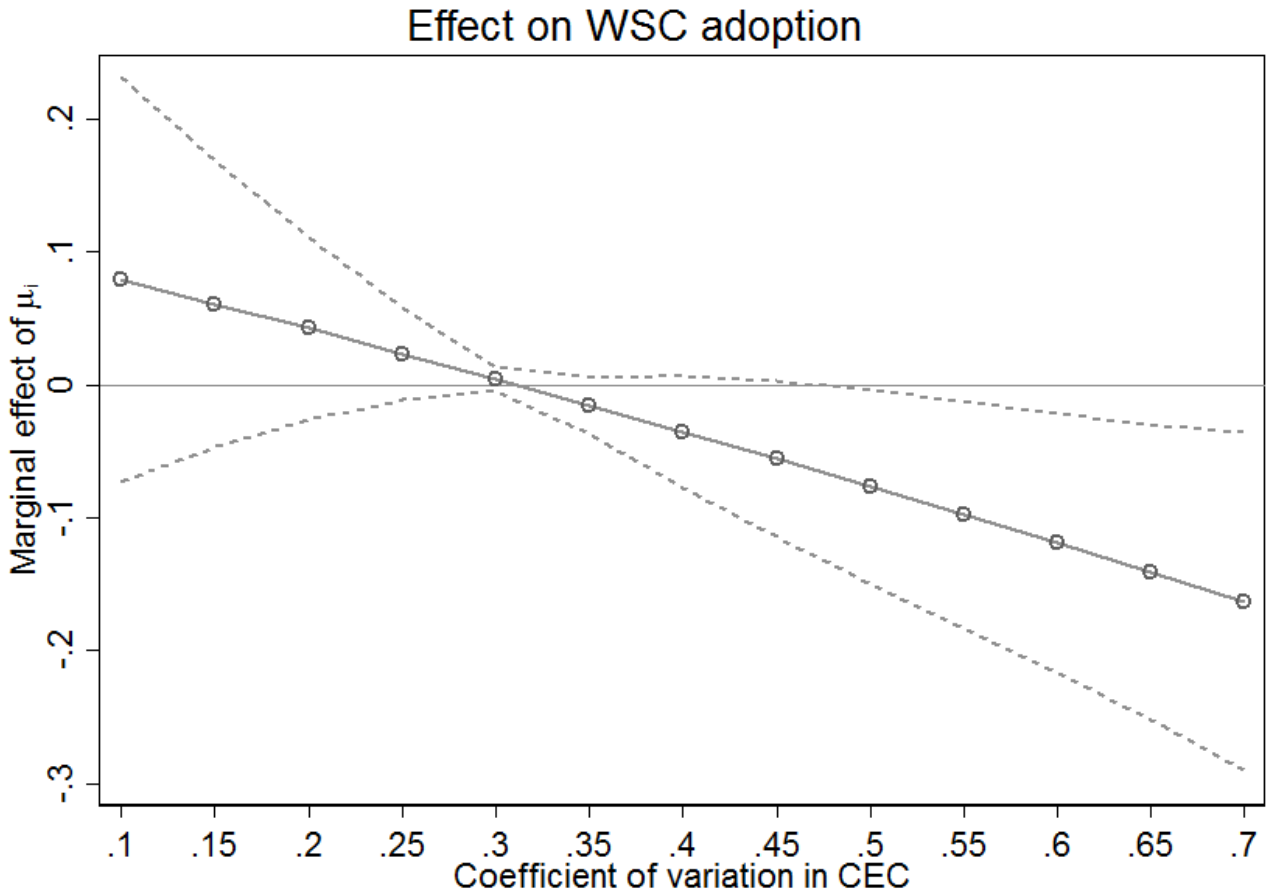

Figure : How impact of avg. signal in nw. varies with heterogeneity

Other hybrid

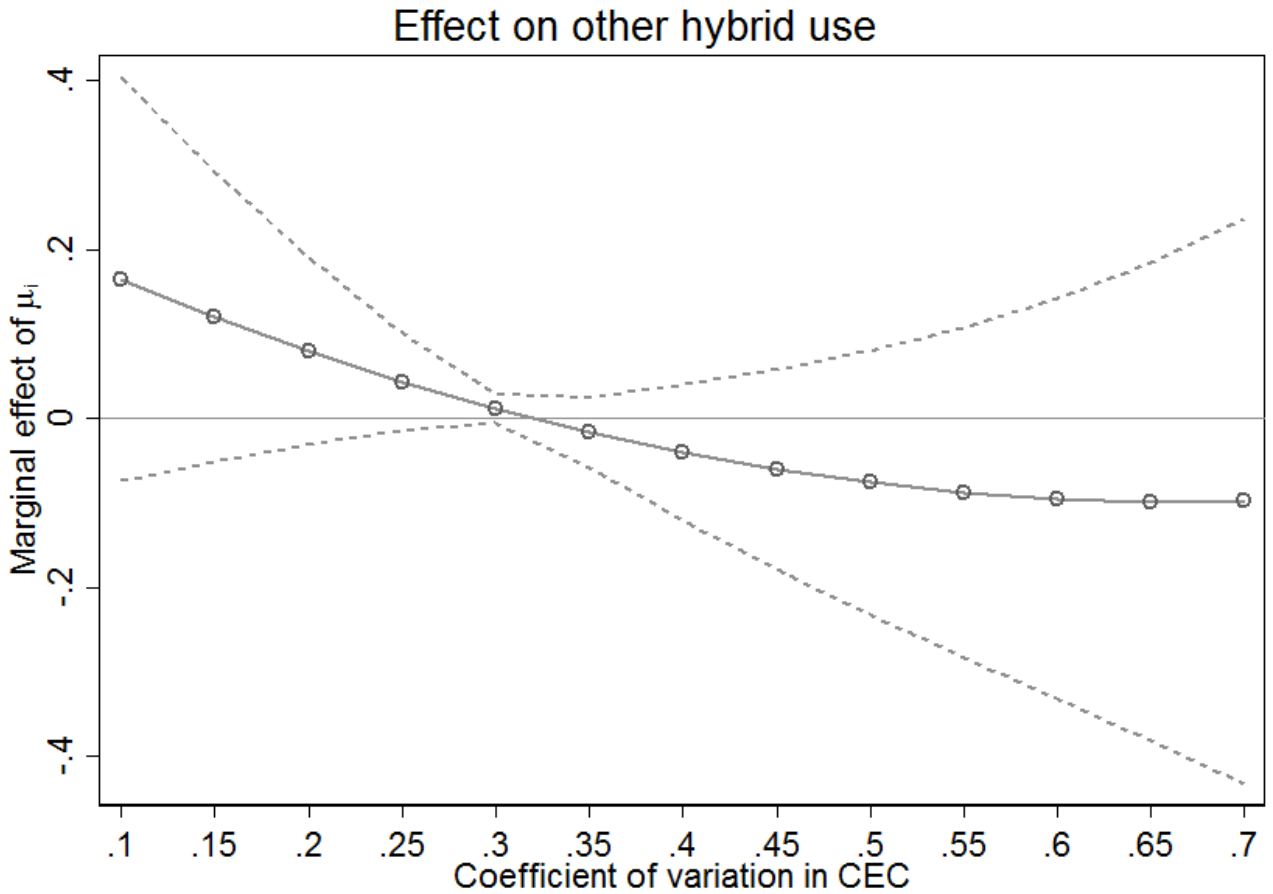

Figure : How impact of avg. signal in nw. varies with heterogeneity

Conclusion

- Use experimental variation in information available through networks to study what farmers learn from their social networks
- Farmers talk and learn from each other BUT heterogeneity that is unobserved to farmers makes them rely less on information from their peers
- Can help us understand why some innovations diffuse slowly
- Can inform policy:
  - when will broad-based extension programs be successful?
  - when do we need to promote individual learning?
- Also useful for thinking about other stochastic tehcnologies