MwAPATA CAPACITY BUILDING SEMINAR: USING RCTs IN AGRICULTURAL DEVELOPMENT ECONOMICS

FEATURED STUDY:

Incentive Mechanisms for Smallholder Farmers to Exploit Price Arbitrage Opportunities for Grain Legumes: Experimental Evidence from Malawi.

By

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Office of Foreign Disaster Assistance

Acknowledgements

- Co-authors on the paper featured in today's presentation:
  - Dr. Jacob Ricker-Gilbert
  - Dr. Jonathan Bauchet

About me !!!

- **Research Background :** Research Fellow at the Centre for Innovation and Industrial Research (CIIR) under MUST.
- Extensive experience in econometric methods using observational data, running large RCTs, experimental auctions, and developing math programming models.

- **Research interests**: Poverty and rural development, agricultural technology and innovations, agricultural marketing, food security and food safety.

  - **Today's paper-** Smallholder farmers' post-harvest grain management decisions → Group storage as a grain storage commitment device.

Key discussion objectives

1. Introduction to RCTs basics
2. Use the featured paper to show how to navigate through administering RCTs in practice
3. Exposure to common issues and challenges of administering RCTs

Outline

1. Introduction to RCTs
    - Why RCTs
    - Clustered RCTs
    - When to use RCTs
2. Featured Study Motivations
    - Agricultural commodity price seasonality
    - Smallholders' "sell low and buy high" behavior
3. Literature and contributions
4. Research objectives
5. Methods
    - Study setting, sampling and randomization
    - Experimental design
    - Power calculations in practice
    - Data collection
    - Treatment effects estimation
6. Main Results of featured paper
7. Conclusions and Policy Implications

Introduction to RCTs

Why Randomized Control Trials?

- The field of development economics has just been added to the list of Nobel prizes in 2019.

- Any guesses which research methods are accredited for these Nobel prizes???

Introduction to RCTs

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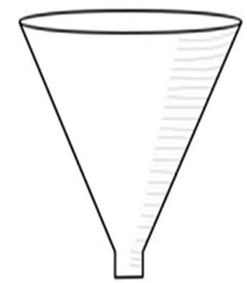
Randomized Control Trials

- 3 Nobel prizes : Duflo ; Banerjee and Kremer for their use of RCTs in development economics
- YES! RCTs are currently big deal in development economics

Introduction to RCTs

Why Randomized Control Trials?

- RCTs involves comparison of intervention group(s) to control group
- at least 2 groups:-Featured paper had three intervention groups and a control group.
- Reliable way of estimating causal impact of interventions
- Useful for project impact evaluations.
    - ✓Pilot project with plans for scale-up



Introduction to RCTs

Why Randomized Control Trials?

- ❑Key feature of RCT is **random assignment** of subjects to groups

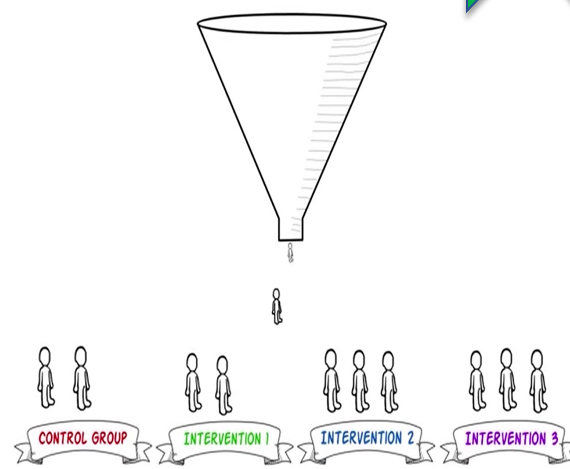
- ❑This helps to eliminate confounding factors by ensuring study groups are equalized.

- ❑Level of randomization could be at individual level or cluster level.
  - ✓Study setting
    - High likelihood of contamination
    - Inclusiveness for ethical reasons
  - ✓ Data availability
    - Limited sampling frame at individual level
  - ✓Budget limitations

Introduction to RCTs

Clustered Randomized Control Trials

- ❑Featured paper in this seminar used a clustered RCT with 3 interventions.
  - ✓Random assignment was at farmer club
- ❑Clustered RCTs have their own complexities in terms of design and analysis
  1. Requires more participants for a given statistical power
  2. Need to factor intra-cluster correlation (ICC) in power calculations typically based on estimates from baseline study or literature.
  3. Analysis requires clustering of std. errors as well since outcomes for subjects in same cluster may be correlated.



Introduction to RCTs

When are RCTs appropriate?

- ❑When we have SMART impacts i. e. Specific, Measurable, Achievable, Realistic, Timely.
  - ✓Not appropriate for outcomes are hard to measure
  - ✓Not suitable when quick answers are required
    - Exceptions depending on type of interventions and outcomes e. g. Food safety information RCT vs. WTP

- ❑Requires strategic planning as cannot be undertaken retrospectively
  - ✓Monitor control group for contamination
- ❑Require large samples-not suitable when have very low units of analysis limits achievement of randomization

Featured Study Motivation

Agricultural Commodity Price Seasonality in SSA

- In SSA agricultural commodities, such as soybeans and groundnuts, often exhibit large seasonal price fluctuations that offer smallholders an opportunity to maximize their agricultural returns.

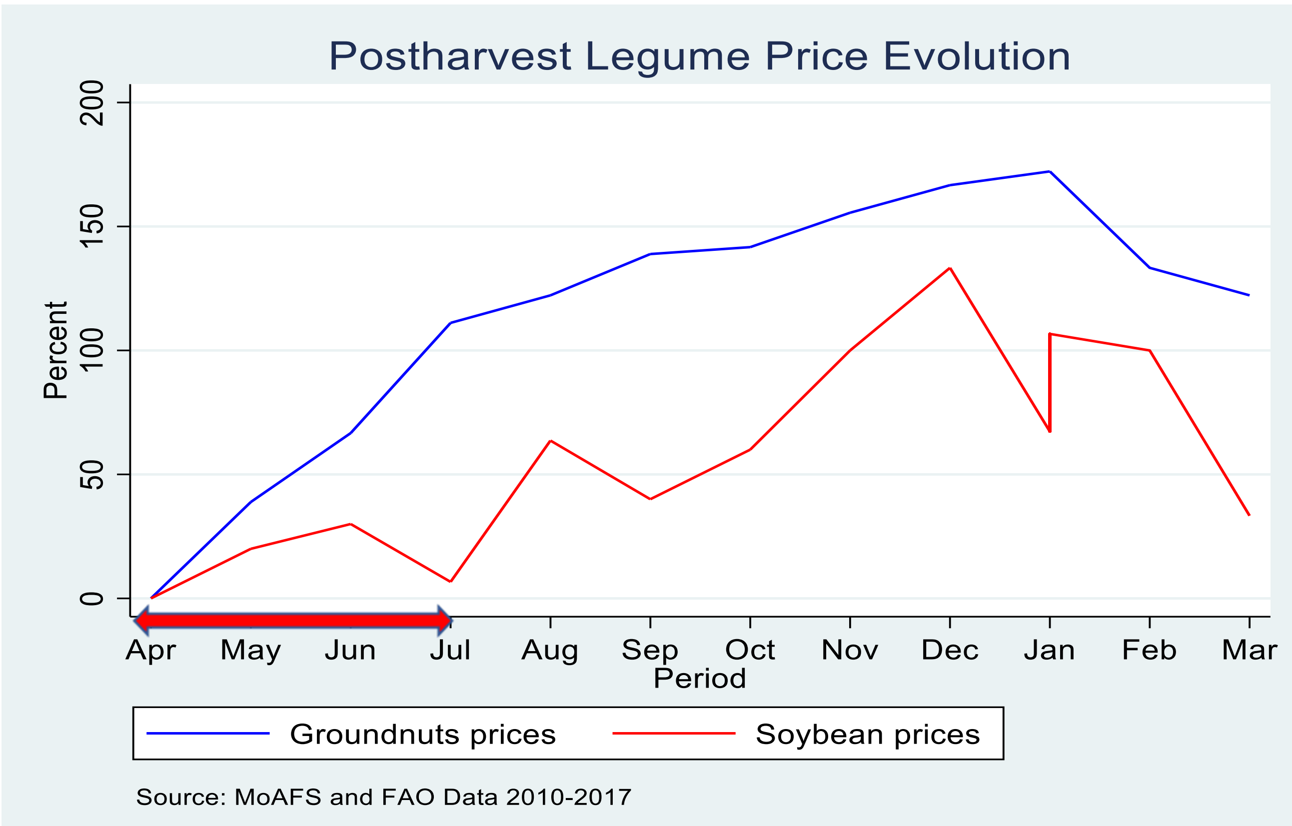
    - See Gilbert, Kaminski & Christiaensen, 2017; Burke et al. 2019; Kaminski, Christiaensen & Gilbert, 2014.

- However, majority of smallholders in SSA are unable to capitalize on these price arbitrage opportunities.

- In fact, smallholder farmers are often involved in what is considered "*the selling low and buying high phenomenon*" (Burke et al., 2019; Stephens and Barrett, 2011; Gabriel and Hundie, 2006).

Featured Study Motivation

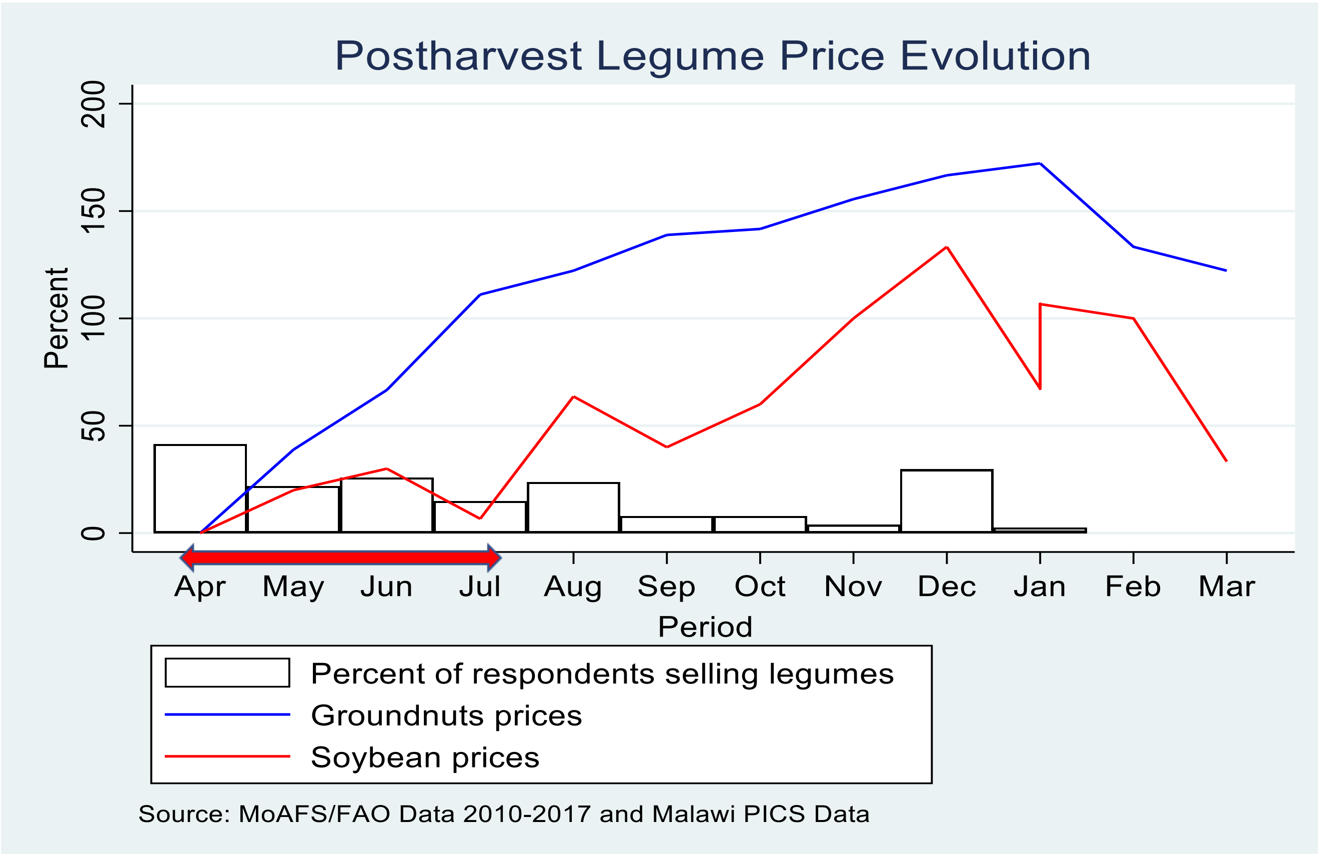
Agricultural commodity price seasonality in SSA



- Average legume price changes after the onset of Harvest (April).
- Substantial increase in prices.

Featured Study Motivation

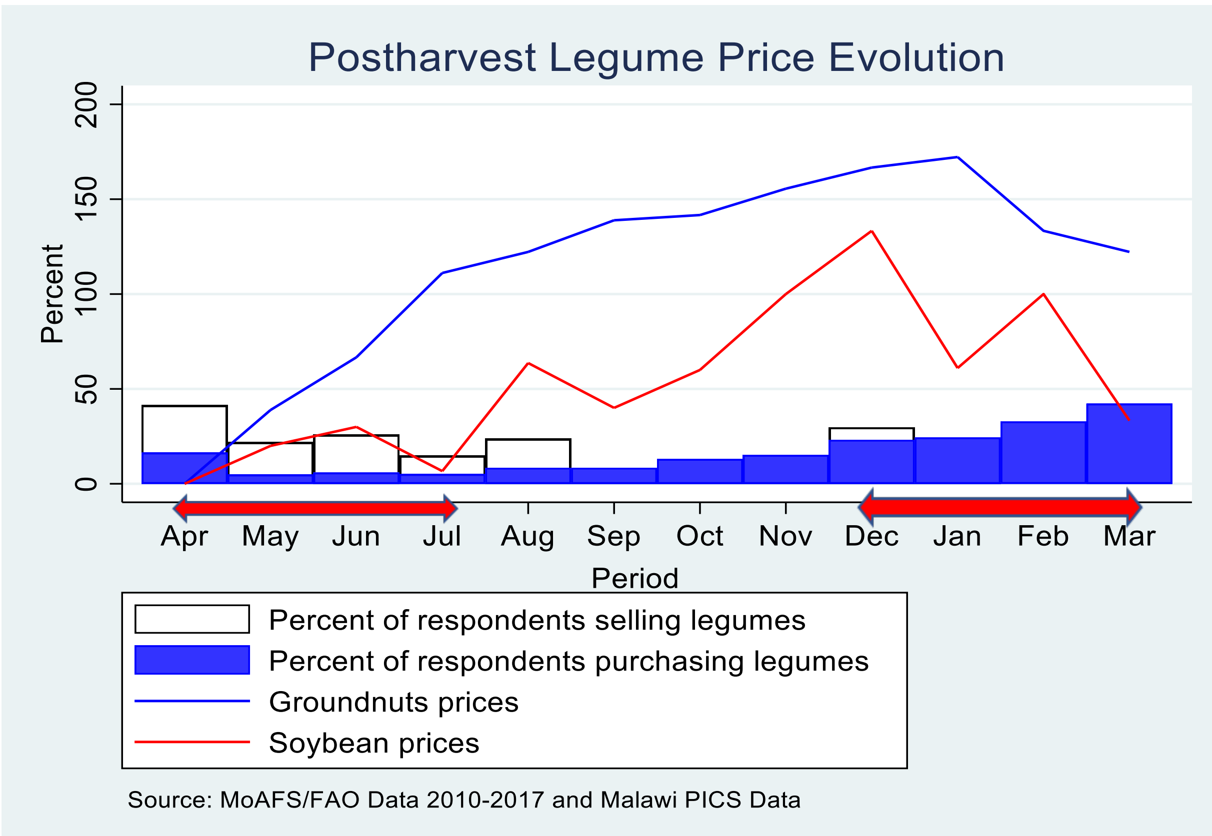
"Sell low and buy high" phenomenon



- Average legume price changes after the onset of Harvest (April).
- Substantial increase in prices.
- At baseline close to 62 % of respondents had their largest legume sales at **harvest season (April-July)**.

Featured Study Motivation

"Sell low and buy high" phenomenon



- Average legume price changes after the onset of Harvest (April).
- Substantial increase in prices.
- At baseline close to 62 % of respondents had their largest legume sales at **harvest season (April-July).**
- About 72 % of respondents had the most purchases in **lean season (December-March).**
- 46% sell low-and buy-high

Literature and Contributions

Why sell-low & buy-high?

Lack of effective storage technology (Kadjo et al. 2018).

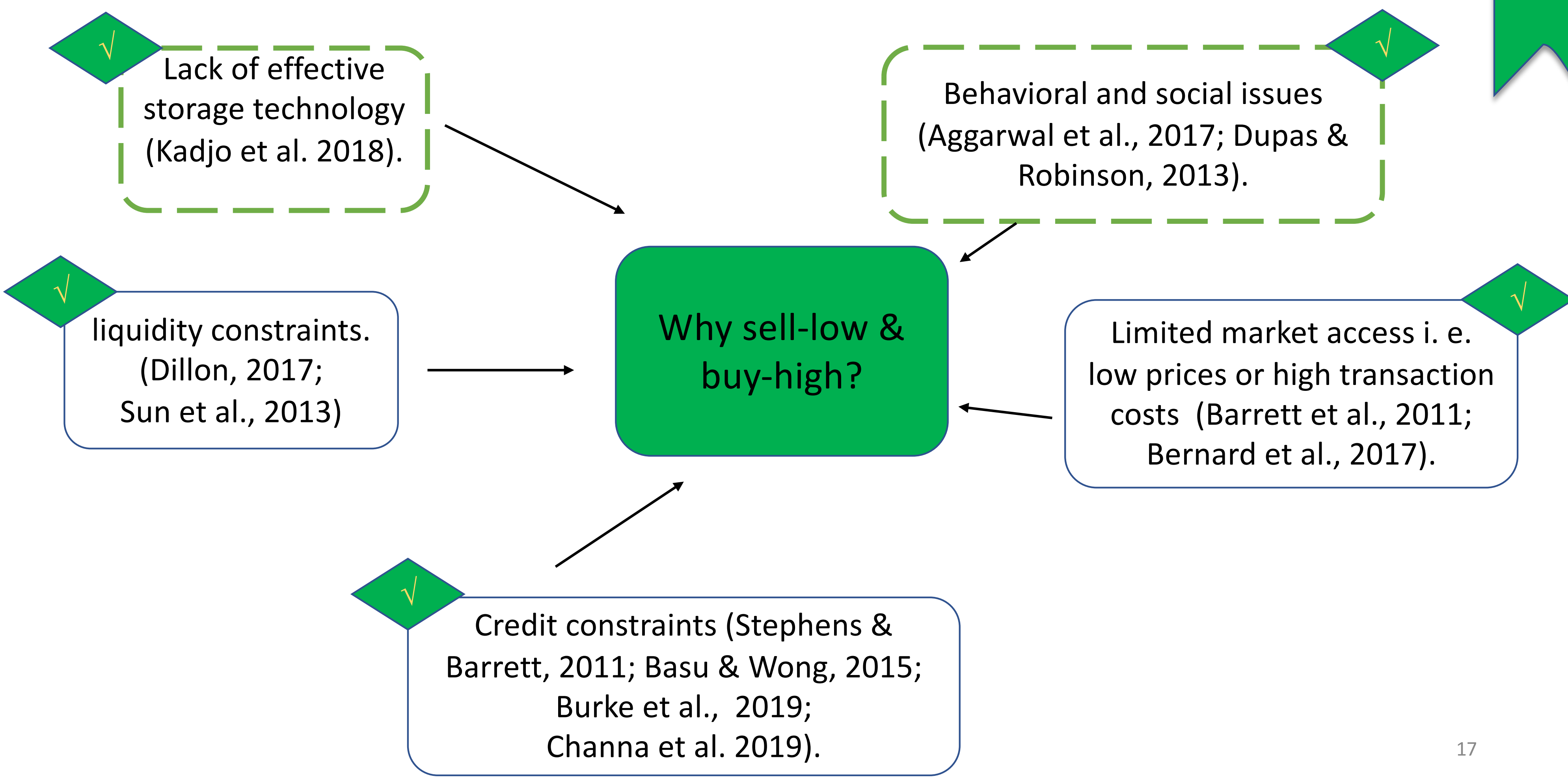
Behavioral and social issues (Aggarwal et al., 2017; Dupas & Robinson, 2013).

liquidity constraints. (Dillon, 2017; Sun et al., 2013)

Limited market access i. e. low prices or high transaction costs (Barrett et al., 2011; Bernard et al., 2017).

Credit constraints (Stephens & Barrett, 2011; Basu & Wong, 2015; Burke et al., 2019; Channa et al. 2019).

Literature and Contributions



Research Question and Objective

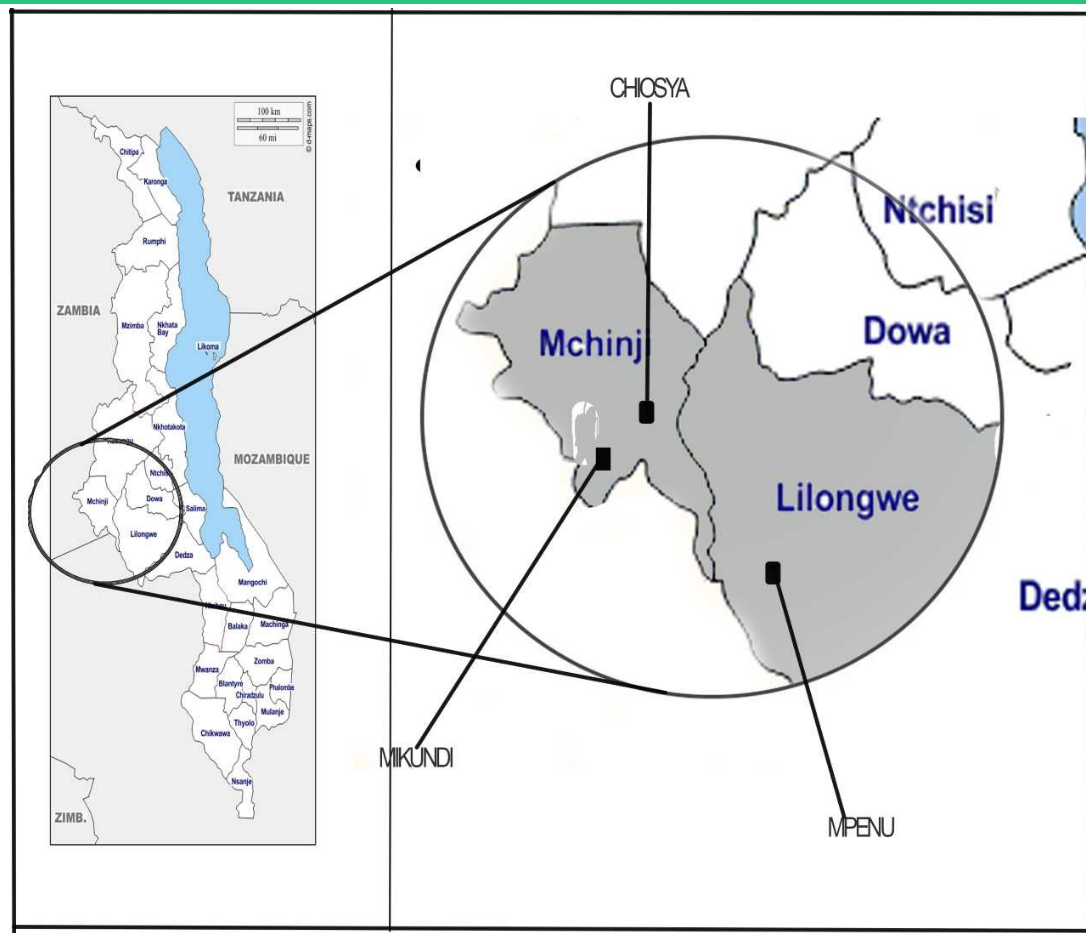
What is the GAP?

- **Objectives:**
  - Estimate the impacts of an improved storage technology along with two storage commitment devices on smallholders’ legume storage behavior.
  - Estimate and compare impact of the two storage commitment devices on smallholders’ legume storage behavior.
  - **Impact evaluation for possible scale up**
- **SMART Outcomes include** quantity stored at harvest, weeks stored before largest sell, total sales, inventories, net sales (kgs), & net sales value(MK).
- A clustered RCT with three storage interventions was implemented.
  - **Treatment 1** → Storage technology
  - **Treatment 2** → Storage technology & storage commitment device at village level
  - **Treatment 3** → Storage technology & storage commitment device at community level

Methods

Study Setting, Sampling and Randomization

- ❑Target the central region of Malawi.
  - ➢Mchinji and Lilongwe districts.
- ❑Predominately the major agricultural region in the country.
- ❑Key producers of legumes e. g. soybeans, groundnuts.



Methods

Study setting, sampling and randomization

- ❑ There is an active network of farmer organizations in Malawi.
- ❑ We worked with the National Smallholder Farmers' Association of Malawi (NASFAM).
- ❑ It is the largest smallholder organization with over 43 associations across the country.

NASFAM STRUCTURE

Association	• Up to 6 Assoc/ district • 21 GACs /Assoc. on average
Group Action Center (GAC)	• At community level • 15 clubs/ GAC on average
Club	• At village level • 10 farmers /Club on average
Farmer	• At household level

Methods

Study setting, sampling and randomization

NASFAM STRUCTURE

How are they organized?	Who is in study?	How to sample in practice?
Innovations Promoting Centers (IPCs) 14	2 IPCs	Purposively
Associations (6-15 per IPC)	3 Associations 1 in Lilongwe 2 in Mchinji	Pre-assigned on PC
Group Action Center (GAC) (8-30 per Association)	12 GACs per Association Randomly selected	Pre-assigned on PC
Clubs (12-30 per GAC)	Randomly selected 12 clubs per selected GAC	Pre-assigned on PC
Farmers (10-15 per club)	Randomly select 5 farmers per selected club	

Methods

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Clubs (12-30 per GAC)	Randomly selected 12 clubs per selected GAC	Might need replacement in field
Farmers (10-15 per club)	Randomly select 5 farmers per selected club	

Methods

Study setting, sampling and randomization

NASFAM STRUCTURE

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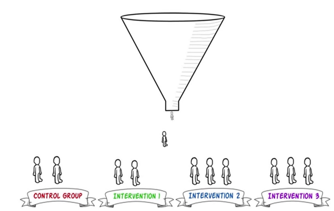
Methods

Study setting, sampling and randomization

- ❑ All farmers were informed about the research surveys through NASFAM lead farmers in their villages.
- ❑ During survey, 5 farmers per club were randomly selected regardless of club size or number of farmers in that club that showed up.
  - ✓ Analysis uses sampling probability weights, and these are based on the inverse proportionality to probability of being sampled (Cameroon and Trivedi, 2005).
- ❑ Treatment assignment at club level i. e. clubs randomly assigned to treatment or control groups.
  - ✓ **Clustered RCT where study setting & budget played a role**

    Inclusiveness , contamination, and ignoring already existing cluster would require stratification or making implausible assumptions about ICC



Methods

Experimental design: Interventions

1. **Treatment 1 [PICS Only]**
   a. Farmers received 2 PICS bags (100 kg each).
      - ✓ Trained how to use the bags.
      - ✓ Stored **at home**

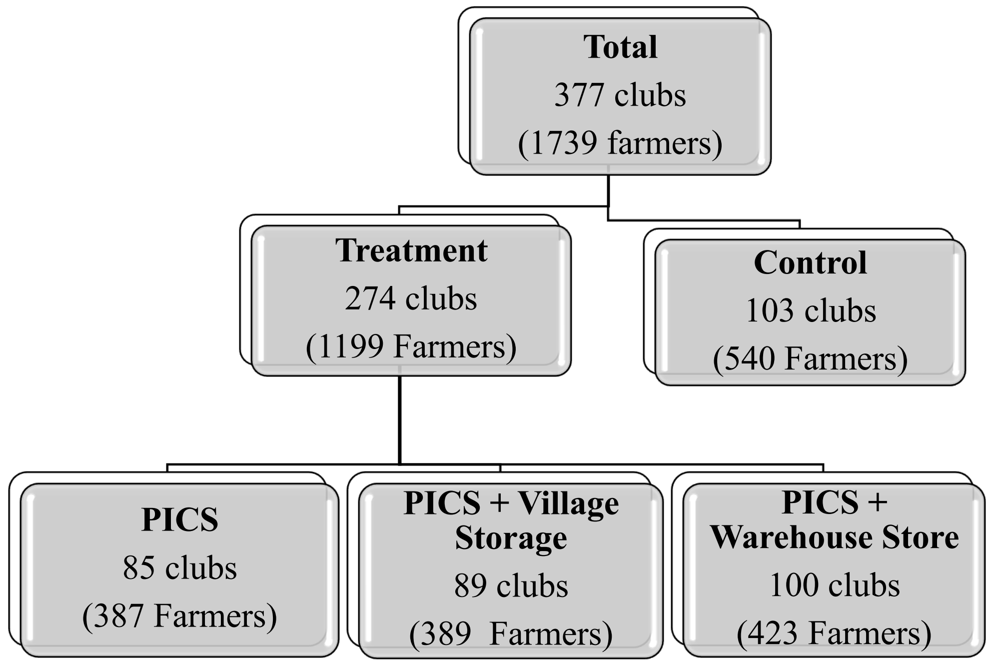
2. **Treatment 2 [PICS + Village group store]**
   a. Farmers also received 2 PICS bags & training.
   b. Farmers stored in groups with their club **within their village**.
   c. Grain deposit and withdraw conditions agreed at club level.

3. **Treatment 3 [PICS + Warehouse group store]**
   a. Farmers also received 2 PICS bags & training.
   b. Farmers stored in groups at centralized NASFAM warehouse in **their community further way from home**.
   c. More than 1 club stored at each warehouse and deposit & withdraw conditions were stricter and agreed upon at warehouse level.

Methods

Experimental design: Interventions

- Evaluate treatment effects (ITT) of our storage interventions.
- **Outcomes:** quantity stored at harvest, weeks stored before largest sell, total sales, inventories, net sales (kgs), & net sales value(MK).
- Recruited 377 clubs based on minimum power calculation requirement of 75 clusters per group and 5 farmers per cluster for ICC of 0.1 and MDE of 0.33.



Methods

Sample size: power calculations in practice (Ex-ante)

- ❑The power of the design is the probability to reject the hypothesis of zero effect for a given effect size and statistical significance level (Duflo et al ,2008).
  - →Ability to pick up or detect the impact of an intervention when its actually there

❑Power Formula (MDE):

Significance Level

Variance

Effect Size

Power

$$EffectSize = \left(t_{(1-\kappa)} + t_{\alpha}\right) * \sqrt{\frac{1}{P(1-P)}} * \sqrt{\frac{\sigma^2}{N}}$$

Proportion in Treatment

Sample Size

79

Methods

Sample size: power calculations in practice (Ex-ante)

❑What matters in common language:

1. Effect size/ MDE/ Cohen d
   - Need more power to be able to pick up a small effect/change
2. Sample size
   - Need more observation to be able to pick up a small effect/change
3. Variance
   - Noisy outcomes require more power and more observations to be able to pick up a given effect
4. Proportion of sample in T vs. C
   - Unequal proportions require more power and more observations while equal proportions help to increase efficiency as they give equivalent distributions
5. Significance level

Methods

Sample size: Power calculations for clustered RCT (Ex-ante)

- For a given N we have less power when we randomize by cluster (unless ICC is zero).
  - **ICC** is the proportion of total variation explained by the within cluster level variance
  - High ICC → low **m** (observation per cluster) and large **M** (number of clusters per group)

- Number of cluster key determinant of power for clustered RCTs

- Power with clustering:

Effect Size
Significance Level
Variance
Power

$$\frac{EffectSize}{\sqrt{1+\rho(m-1)}} = \left(t_{(1-\kappa)} + t_{\alpha}\right) * \sqrt{\frac{1}{P(1-P)}} * \sqrt{\frac{\sigma^2}{N}}$$

ICC
Average Cluster Size
Proportion in Treatment
Sample Size

Methods

Sample size: What you need for power calculations in practice (Ex-ante)

- Example of clustered RCT as used in the featured paper

a) Decide on number of treatments

b) Get parameters required to calculate sample size:

1. **Set power (1-β), typically 0.8 or 0.9;**
2. **Set Significance level or α typically α =0.05;**
3. **Set allocation ratio or Proportion of Sample in T vs. C typically P=0.5;**
4. Set delta or effect size for T vs C based on at baseline or literature or national data
5. Estimated mean of the outcome(s) at baseline or literature or national data
6. Estimated std. Dev. of outcome(s) at baseline or literature or national data
7. Estimated ICC or ρ at baseline or literature or national data

c) Calculate sample size , resulting budget and adjust parameters accordingly

Methods

Power Calculations for the Group storage experiment (RCT1)

Parameter sources for the key outcomes

LSMS data 2016 for Mean and Variance of Outcomes				Module detail	Estimates of Intervention Effect Size or Delta		
Legumes	**Mean**	**Std dev.**	**ICC(village)**	**Source**	**Channa et al 2020**	**Burke et al 2019**	**Aggarwal et al 2018**
Stored at Harvest(kg)	261	158	0.1	Ag Module I: I40 +I35	29% more	X	29 to 55
Storage length (Weeks)	11	8	0.0005	Ag module I: I24	X	X	4 weeks
Total Sale Revenue(MK)	159,600	78,530	0.1	Ag module I: I03	K30, 000 - K38, 000	K3,800-K13,500	10-15 %
Inventory	180	355	0.006	Ag Module I: I40	30% increase (223)	25% more inventory	X
Net Sales (kg)	363	569	0.03	Ag Module I: I02	128-135	24 – 46 kg more	X
Net Sales Value (MK)	125,150	94,150	0.04	Ag Module I: I02	50% (233)	X	X

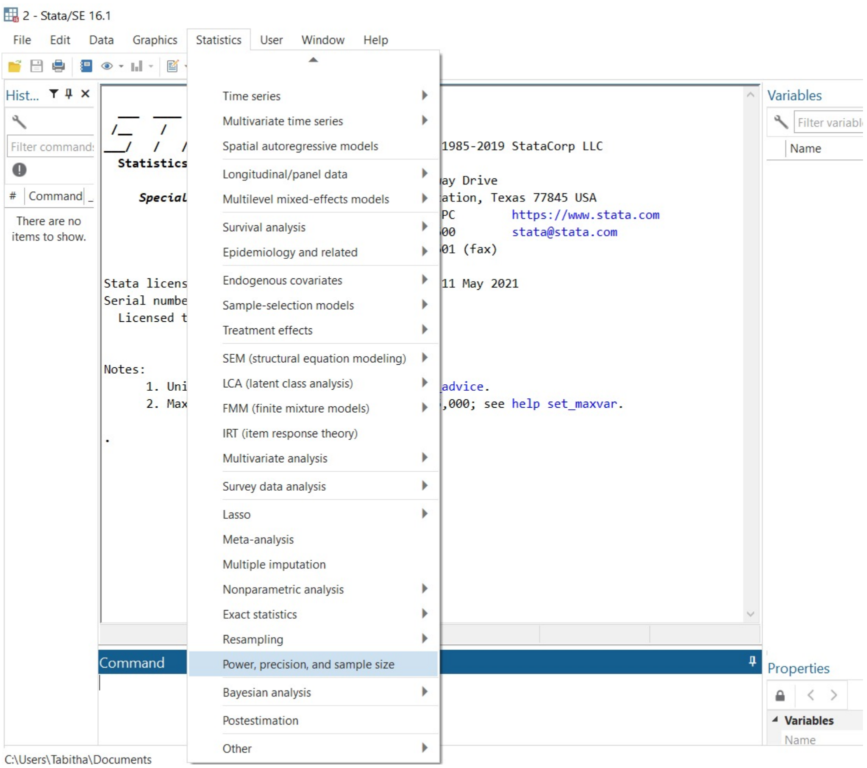
Set parameter for calculations

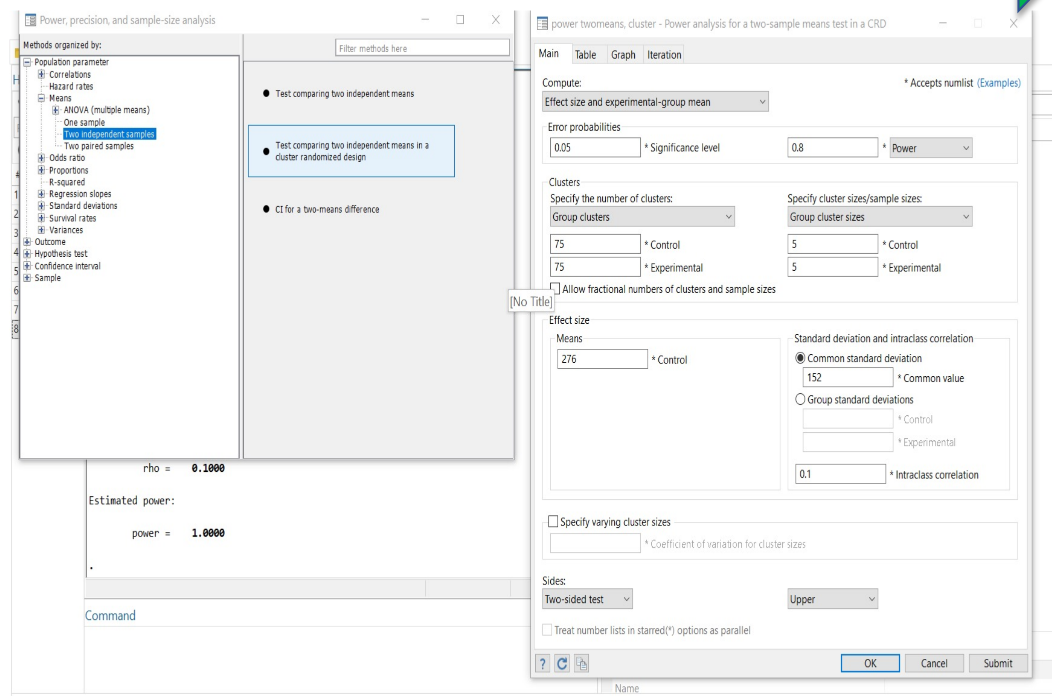
Means and ICC at village (club) level from the World Bank agricultural household survey 2016

Key Outcomes	Mean	SE	ICC	SE (4 ICC)	Delta
Storage at harvest (kg)	261	158	0.12	0.028	25
Storage length (Weeks)	11	8	0.08	0.055	1
Sales revenues (MK)	159,600	78,530	0.0001	0.002	10,000

Methods

Using Stata for power calculations

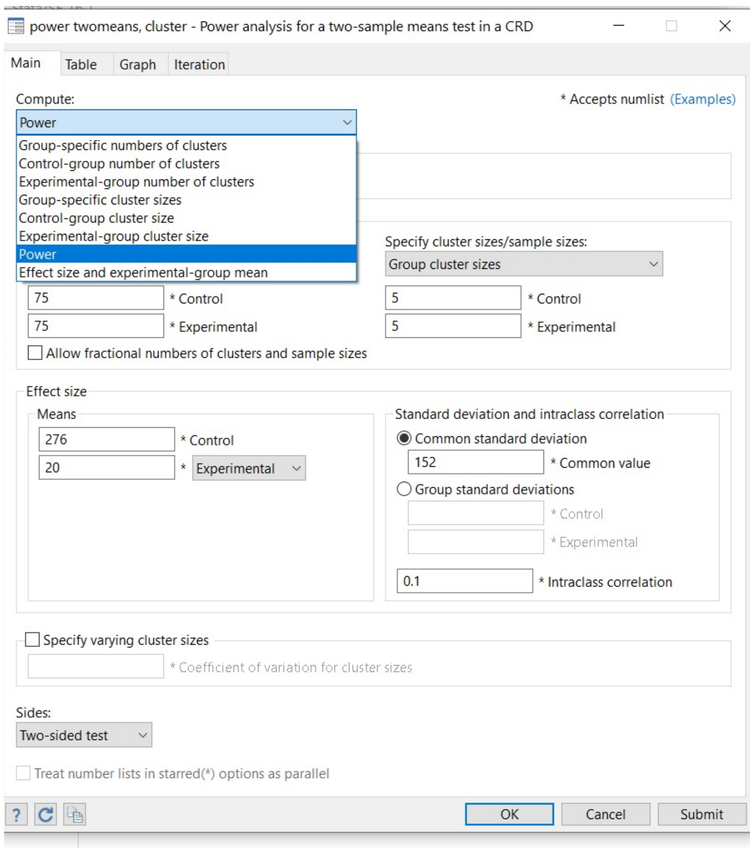




- ❑Statistics → Power, precision and sample size → Means→ Two independent samples → Test for two independent means in a clustered randomized design

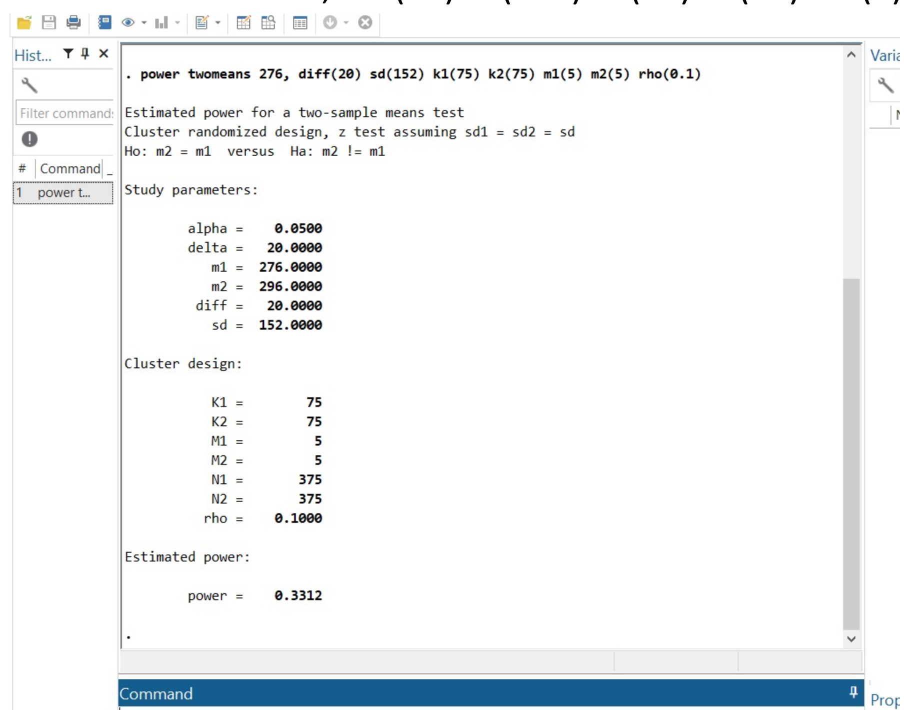
Methods

Using Stata for power calculations



Getting MDE

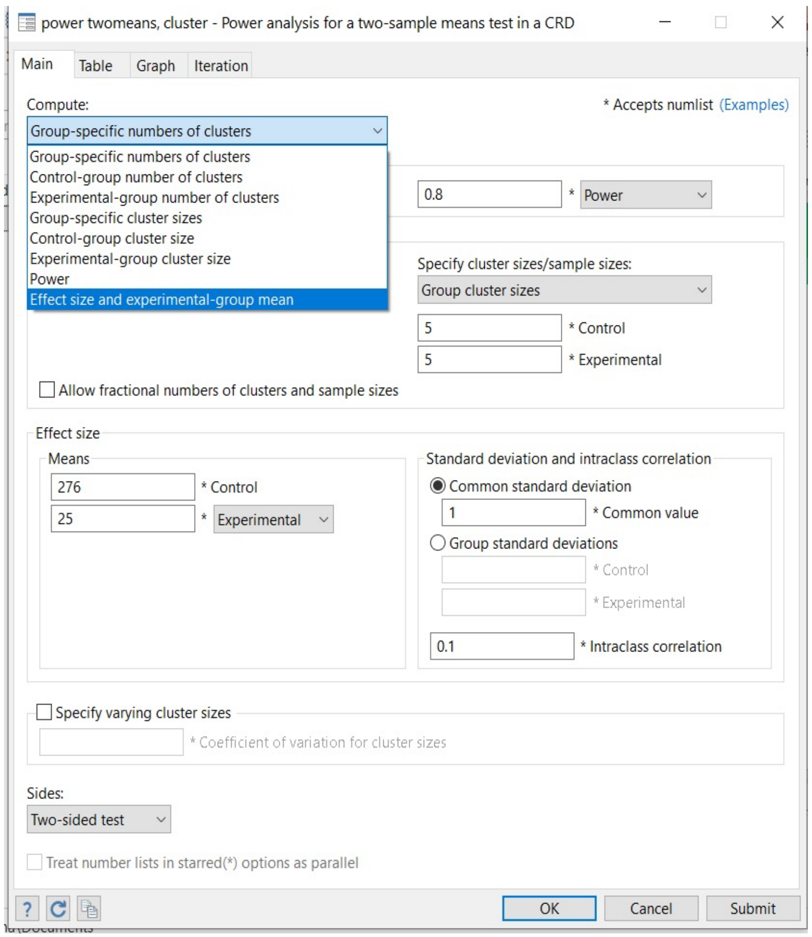
power twomeans 276, diff(20) sd(152) k1(75) k2(75) m1(5) m2(5) rho(0.1)



MDE of 0.2 is small, 0.5 is Medium and 0.8 is large, Duflo et al 2007

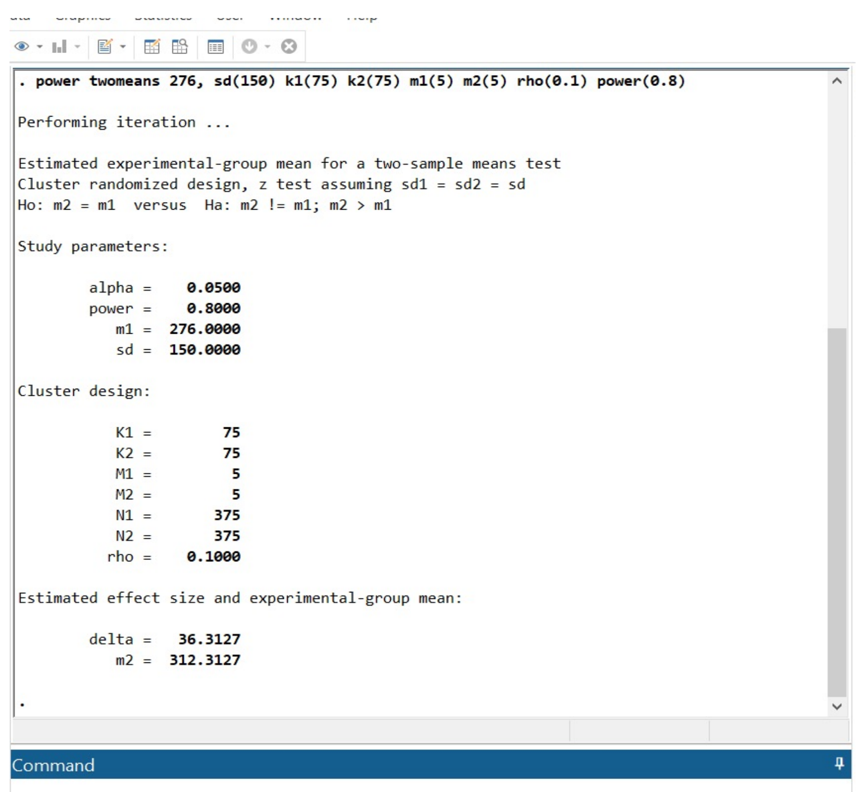
Methods

Using Stata for power calculations



Getting Delta

power twomeans 276, sd(150) k1(75) k2(75) m1(5) m2(5) rho(0.1) power(0.8)



Methods

Data collection and follow-ups

- Baseline study was conducted April-May of 2018 using a structured & pre-tested questionnaire.
  - Our sample has 1736 legume farmers.

- This was followed by implementation of the storage interventions.

- Follow-up data collected after every 4 months → collecting data on outcome variables in August 2018; December 2018.
  - Following estimation framework by Burke et al. (2019), evaluate variations in treatment effects across quarters.
  - Increase statistical power.

Methods

Data collection and follow-ups

Baseline Balance : Did randomization work?

- ❑No difference in observable at baseline across groups
- ❑Joint orthogonality test using multinomial probit suggests variables are balanced across groups at baseline ($F=125$; $p=0.1258$).

Treatment effects

- ❑Intention to Treat effects (ITT) –effect of treatment **assignment** i. e. for everyone regardless of compliance status
- ❑Average Treatment effect (ATE) – effect of treatment for everyone
- ❑Local Average Treatment effect – for compliers only

Methods

Treatment effects estimation

- We use ANCOVA to estimate intention to treat (ITT) effects on outcomes of interest.

Aggregate Effects:

$$y_{ij} = \alpha + \beta PICS_j + \lambda Villagestore_j + \rho Warehousestore_j + \gamma A_j + \partial Q_{ij} + \delta yo_{ij} + \varepsilon_{ij} \quad (1)$$

Quarterly Effects:

$$y_{ijt} = \alpha + \sum_{d=2}^{d=3} \beta_{\mathrm{d}} Q_{d\,jt} * PICS_{jt} + \sum_{d=2}^{d=3} \lambda_{\mathrm{d}} Q_{d\,jt} * Villagestore_{jt} + \sum_{d=2}^{d=3} \rho_{\mathrm{d}} Q_{d\,ijt} * Warehousestore_{jt} + \sum_{d=2}^{d=3} \partial_d Q_{d\,ijt} + \gamma A_{jt} + \delta yo_{ij(t-1)} + \varepsilon_{ijt} \quad (2)$$

- y_{ij} is observed outcome; $PICS_j$, $Villagestore_j$ and $Warehousestore_j$ are binary variables =1 if household received Treatment 1, 2 & 3 respectively for *i*=1,2,…, *n* farmers in club *j*.
- $yo_{ij(t-1)}$ is the baseline (lagged) outcome value for ANCOVA analysis, A_{jt} & $Q_{d\,ijt}$ are a set of association & period dummy variables respectively and our standard errors clustered at club level.

Methods

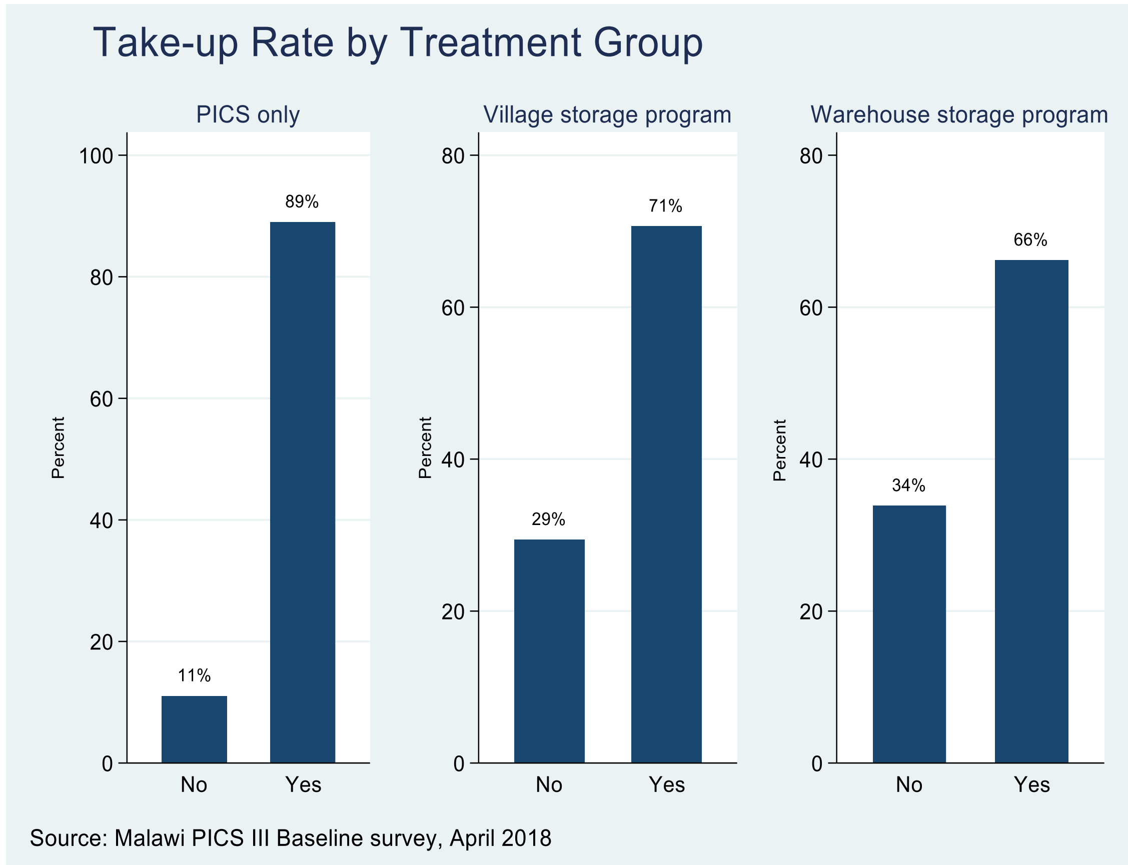
Treatment effects estimation : Common Issues of concern for RCTs

1. Compliance Rate

- ❑Not all treated households complied with treatment interventions.
- ❑Example of credit intervention RCT with zero take up rate

2. **Multiple Hypothesis Testing**

- ❑Deal with p-hacking or familywise error rate if you have multiple hypothesis
- ❑Our results are robust even after adjusting for multiple hypothesis testing using Andersons' sharpened q-values.



Methods

Treatment effects estimation : Issues of concern for RCTs

3. Attrition

- Attrition at 7% & 14% for 1st and 2nd follow-up surveys, respectively.
- Results suggest attrition is not random & we account for it in our analysis.

Variables	**Overall rate**	Control	PICS Only	Village program	Warehouse program	p-values
Follow-up 1 Attrition	**7% (127 households)**	2.5%	1%	2%	1.5%	0.0057
Follow-up 2 Attrition	**14% (236 households)**	6%	2%	3%	3%	0.4111

Methods

Treatment effects estimation : Issues of concern for RCTs

4. Contamination

Contamination	Percent of sample in control group
Number that Purchase PICS bags	2% (12 households)
Number that used PICS to store legumes	0.18% (1 household)
Number that stored legumes in groups	0
Number that stored legumes in warehouse	0

Main Results

Table 1.1: Aggregate Treatment Effects on Key Outcomes(ITT)

	(1)	(2)	(3)	(4)	(5)	(6)
VARIABLES	**Storage at harvest(kg)**		**Weeks stored largest sale**		**Sales revenue (MK)**	
=1 for PICS only (T1)	32*	34*	1.7*	1.5*	20,919*	23,161**
	(19)	(19)	(0.9)	(0.9)	(11,806)	(11,528)
=1 for PICS+ Village group store (T2)	73***	74***	2.5***	2.4***	28,442**	30,073***
	(20)	(19)	(0.9)	(0.9)	(11,671)	(11,440)
=1 for PICS+ Warehouse group store (T3)	42**	42**	1.8*	1.8*	23,849*	23,763*
	(18)	(18)	(1.0)	(1.0)	(13,632)	(13,280)
Constant	78	62	10.0***	10.4***	107,218***	120,080***
	(51)	(56)	(1.9)	(1.9)	(15,872)	(17,016)
Baseline outcome control	Yes	Yes	Yes	Yes	Yes	Yes
Association controls	No	Yes	No	Yes	No	Yes
Observations	1,358	1,358	1,358	1,358	1,358	1,358
R-squared	0.01	0.01	0.10	0.13	0.06	0.06
F-Test	**P-value**	**P-value**	**P-value**	**P-value**	**P-value**	**P-value**
Treatment 1=Treatment 2	0.0412	0.0425	0.3912	0.3505	0.5268	0.5537
Treatment 1=Treatment 3	0.5932	0.6386	0.9667	0.8812	0.8270	0.9636
Treatment 2=Treatment 3	0.0930	0.0908	0.4344	0.4572	0.7444	0.6404

Note: Standard errors clustered at club level in parentheses ; *** p<0.01, ** p<0.05, * p<0.1 & US$1=MK750

Main Results

Table 1.2: Quarterly Treatment Effects on Key Outcomes(ITT)

VARIABLES	(1) **Legume inventories at end of quarter (kg)**	(2)	(3) **Net legume sales(kg)**	(4)	(5) **Net value of sales (MK)**	(6)
Panel A: Four months after harvest season, August 2018 (Quarter 2)						
PICS only (T1)	0.3	2.1	26.8***	27.7***	7,854***	7,847***
	(18.9)	(18.5)	(3.6)	(3.7)	(1,125)	(1,186)
PICS+ Group store at village (T2)	45.5**	47.4**	42.0***	42.7***	12,395***	12,422***
	(21.4)	(21.0)	(1.8)	(1.9)	(583)	(641)
PICS+ Group store at warehouse (T3)	42.6*	45.3*	32.2***	33.1***	9,677***	9,801***
	(23.7)	(23.7)	(2.6)	(2.8)	(907)	(928)
Constant	60.7***	31.2*	5.5*	-1.3	838	-1,490
	(15.5)	(16.9)	(2.8)	(4.9)	(853)	(1,562)
Baseline outcome control	Yes	Yes	Yes	Yes	Yes	Yes
Association controls	No	Yes	No	Yes	No	Yes
Observations	3,114	3,114	3,114	3,114	3,114	3,114
R-squared	0.01	0.01	0.10	0.11	0.09	0.09
Treatment 1=Treatment 2	**0.0177**	**0.0191**	**<0.001**	**0.0001**	**0.8304**	**0.8237**
Treatment 1=Treatment 3	**0.0476**	**0.0437**	**0.2000**	**0.2067**	**0.7537**	**0.7202**
Treatment 2=Treatment 3	**0.9203**	**0.9557**	**0.0001**	**0.0001**	**0.9349**	**0.9112**

Note: Standard errors clustered at club level in parentheses ; *** p<0.01, ** p<0.05, * p<0.1 & US$1=MK750

Main Results

Table 1.2: Quarterly Treatment Effects on Key Outcomes(ITT)

VARIABLES	(1)	(2)	(3)	(4)	(5)	(6)
	Legume inventories at end of quarter (kg)		**Net legume sales(kg)**		**Net value of sales (MK)**	
Panel B: Eight months after harvest season, December 2018 (Quarter 3)						
PICS only (T1)	17.5	19.1	18.7	19.6	7,138*	7,087*
	(14.7)	(14.5)	(12.9)	(12.8)	(4,150)	(4,116)
PICS+ Group store at village (T2)	25.6*	26.9**	27.0*	27.7*	9,214**	9,164*
	(13.2)	(13.0)	(14.9)	(15.0)	(4,684)	(4,712)
PICS+ Group store at warehouse (T3)	0.3	2.5	5.3	6.1	4,301	4,351
	(10.3)	(10.1)	(12.3)	(12.2)	(4,279)	(4,297)
Constant	60.6***	31.2*	5.5*	-1.3	838	-1,490
	(15.5)	(16.9)	(2.8)	(4.8)	(853)	(1,562)
Baseline outcome control	Yes	Yes	Yes	Yes	Yes	Yes
Association controls	No	Yes	No	Yes	No	Yes
Observations	3,114	3,114	3,114	3,114	3,114	3,114
R-squared	0.01	0.01	0.10	0.11	0.09	0.09
Treatment 1=Treatment 2	**0.5464**	**0.6290**	**0.4140**	**0.4167**	**0.3276**	**0.3294**
Treatment 1=Treatment 3	**0.2565**	**0.2355**	**0.1643**	**0.1606**	**0.7928**	**0.8025**
Treatment 2=Treatment 3	**0.0402**	**0.0506**	**0.0461**	**0.0464**	**0.2279**	**0.2358**

Note: Standard errors clustered at club level in parentheses ; *** p<0.01, ** p<0.05, * p<0.1 & US$1=MK750

Main Results

Table 1.3: Aggregate Treatment Effects on Key Outcomes(LATE)

VARIABLES	(1) Storage at harvest(kg)	(2)	(3) Weeks stored before largest sale	(4)	(5) Sales revenue(MK)	(6)
=1 for participation in T1	36*	37*	1.9*	1.7*	23,156*	25,250**
	(21)	(20)	(1.0)	(1.0)	(12,870)	(12,461)
=1 for participation in T2	105***	105***	3.5***	3.4**	40,594**	42,690***
	(27)	(27)	(1.3)	(1.3)	(16,520)	(16,058)
=1 participation in T3	67**	67**	2.9*	2.9*	38,114*	37,925*
	(28)	(28)	(1.5)	(1.5)	(21,732)	(21,199)
Constant	116**	101**	11.3***	11.8***	123,146***	137,094***
	(47)	(50)	(1.7)	(1.7)	(12,690)	(14,721)
Baseline outcome control	Yes	Yes	Yes	Yes	Yes	Yes
Association controls	No	Yes	No	Yes	No	Yes
Observations	1,358	1,358	1,358	1,358	1,358	1,358
R-squared	0.06	0.07	0.01	0.01	0.01	0.01
F-Test	**P-value**	**P-value**	**P-value**	**P-value**	**P-value**	**P-value**
Treatment 1=Treatment 2	0.0067	0.0066	0.1809	0.1602	0.2442	0.2334
Treatment 1=Treatment 3	0.2042	0.2120	0.5346	0.4737	0.4535	0.5205
Treatment 2=Treatment 3	0.1642	0.1686	0.5908	0.6216	0.9123	0.8221

Note: Standard errors clustered at club level in parentheses ; *** p<0.01, ** p<0.05, * p<0.1 & US$1=MK750

Conclusions and Policy Implications

- All three storage interventions significantly helped treated farmers to:
  - ✓Store more legumes at harvest (34 to 74 kgs),
  - ✓Store longer (1 to 2 weeks) as well as
  - ✓Make more revenue from legume sales (MK22,000 to MK29,000; US$1=MK750) compared to control households.

- Out of the two storage commitment devices, the village storage program was relatively more effective at incentivizing farmers to store more at harvest compared to warehouse storage program.

- LATE estimates suggest that this is influenced by the low take-up rate in the warehouse storage program due to
  - Transportation costs
  - Limited desire to store with a larger group outside the farmers' village.

Conclusions and Policy Implications

- This essay estimates the impacts of storage and commitment constraints and findings provide empirical evidence on the effectiveness of the three storage interventions implemented in this study.
  - Guide for policy, development agencies and NGO interested in helping farmers exploit inter-temporal price arbitrage opportunities.
- Findings also help provide empirical estimates of the impacts and effectiveness of warehouse programs such as WRS and village grain banks for smallholders in developing countries.
  - Provides insights on viability of warehouse programs suggesting that incentivizing farmers to store together locally within villages may be more effective than centralized warehouse programs.

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- The project title was "Increasing Smallholder Malawian Farmers' Access to Improved Storage Technology and Credit"

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