# Arbitrage and Integration in African Agricultural Markets

Lauren Falcao Bergquist

ATAI Roundtable
December 7, 2017

# Market Integration

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- Direct welfare implications:
  - Low prices for farmers (main source of income)
  - High prices for consumers (food security, hunger season)
- Indirect implications:
  - Lower output prices may dampen farmers' incentives to invest in inputs
  - Shifts in local supply may affect local market prices, shaping the returns to technologies

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- Search costs (Aker 2010; Bergquist and McIntosh 2017)
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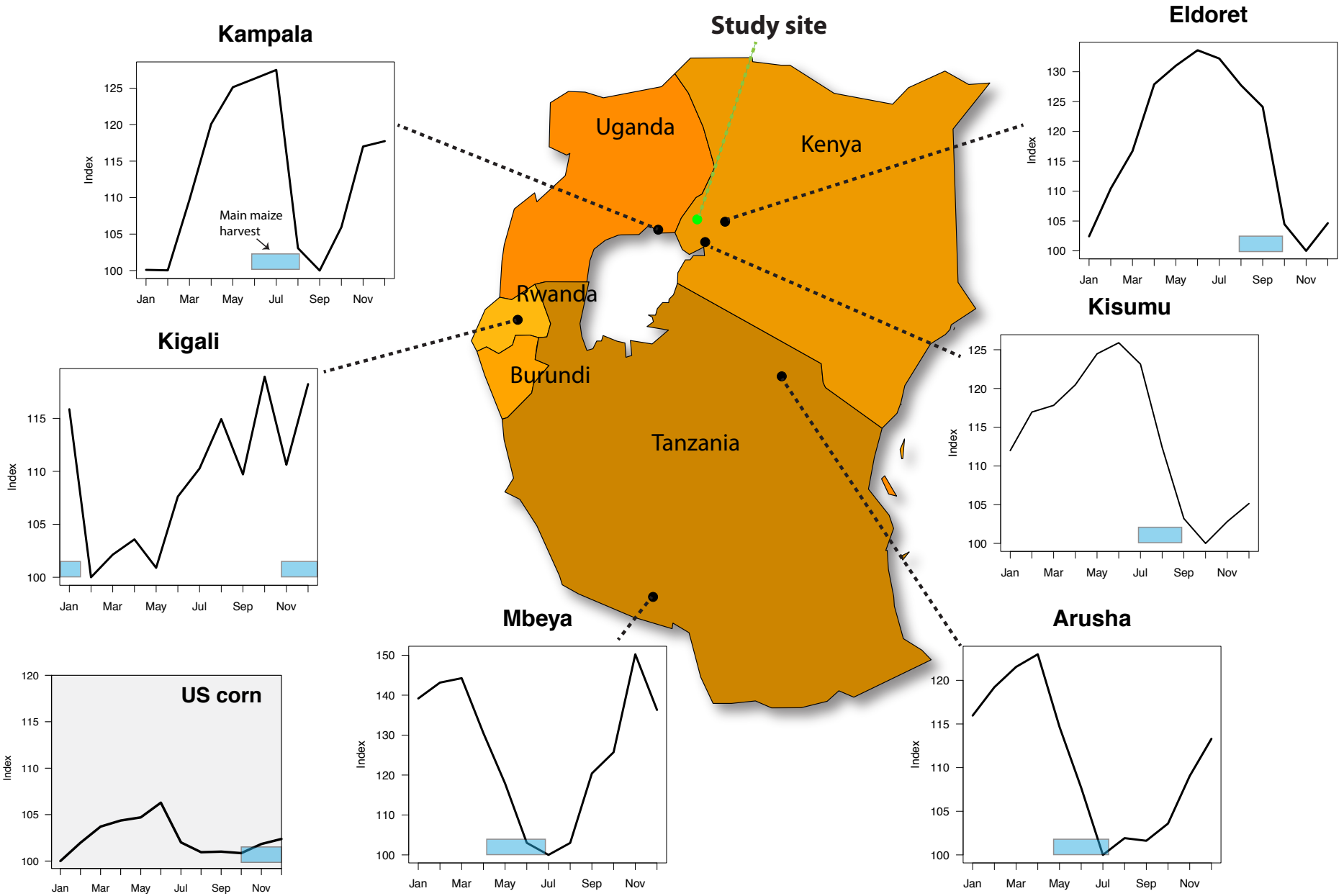
ATAI Research:

1. Causes: identifying and quantifying barriers; testing solutions
2. Consequences: how does (lack of) market integration shape the returns to policy interventions?

# Project 1: Selling Low and Buying High



# An Arbitrage Opportunity

Staple food prices not fixed within the season

Staple grains are storable!

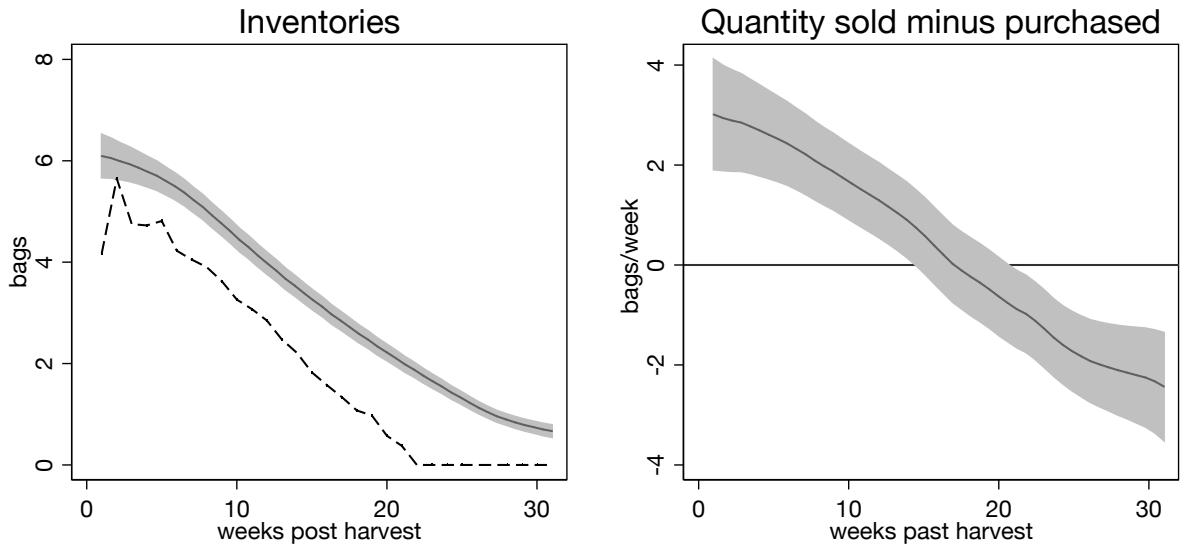
If unconstrained, rural households should store a unit of grain if:

$$\delta E[p_{t+1}] > p_t + c$$

You might think: use storage to *buy low, sell high*

# Sell Low, Buy High

**Sell low, buy high:** farm households appear to be selling low at harvest or buying high later in the season – and often both



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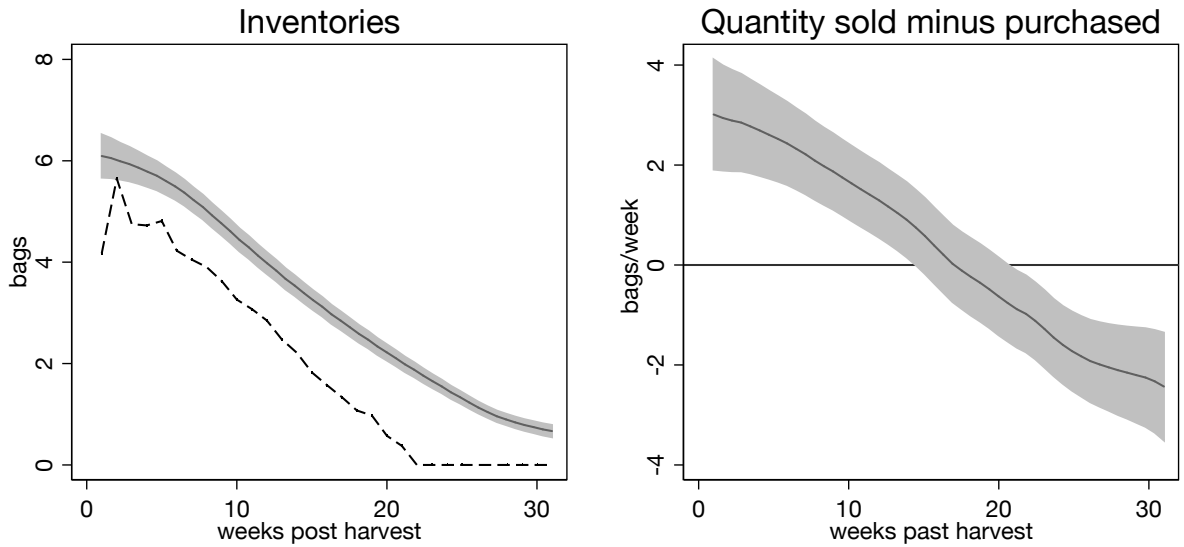


$\Rightarrow$ Median HH in our sample appears to be giving up equivalent of 1-2 months of agricultural wages by selling low/ buying high, instead of the reverse

# Project Overview

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- Loan offer is randomized across farmers
- Density of treatment is randomized across locations

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We repeatedly survey households throughout the year and collect monthly price data at 52 local markets

Two years of replication. Long-run follow-up survey 1-2 years after

# The Setting

Western Kenya, One Acre Fund client farmers growing maize on $\sim$2.4 acre, yielding $\sim$0.8 ton

Seasonal Price Swings

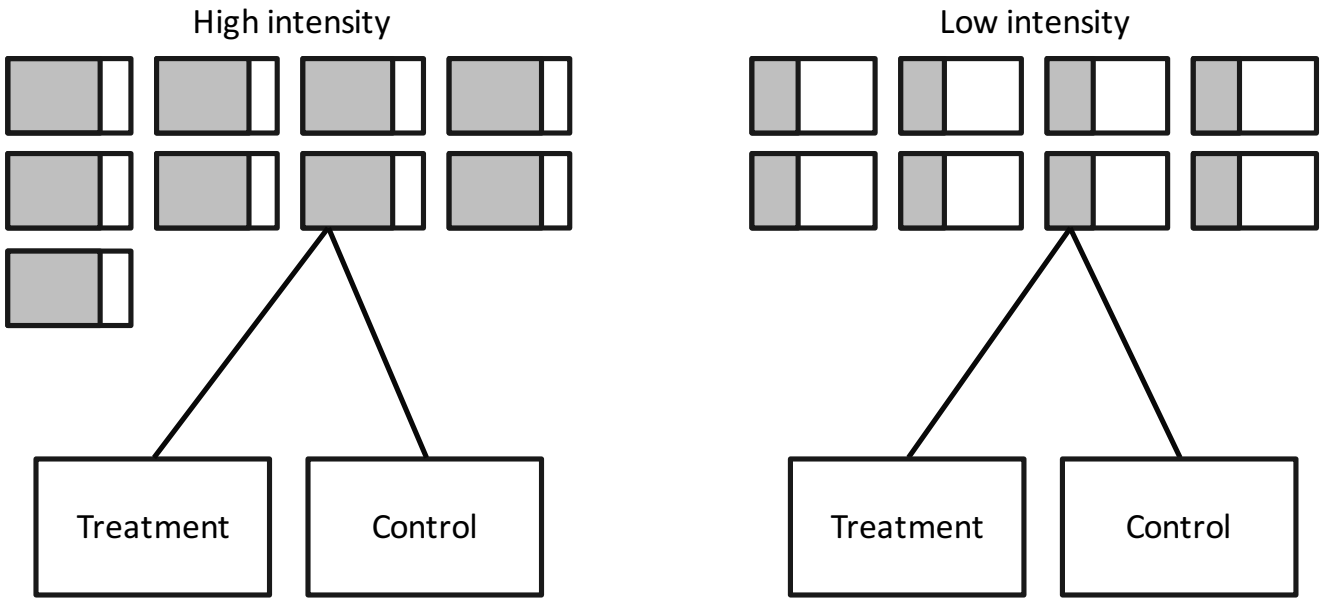
# Loan Details

- Group liability loan
- Offered in post-harvest period
- Loan is “collateralized” by stored maize; farmers can borrow as a function of the number of bags (90kg) they put in storage
- 10% flat interest rate, repay everything within 9 months
- Dynamic incentive: default on storage loan, get kicked out (default $<$2%)
- Average loan size was 8,579Ksh ($\sim$\$98), conditional on take-up
- 63% of those offered took out a loan

# Experimental Design

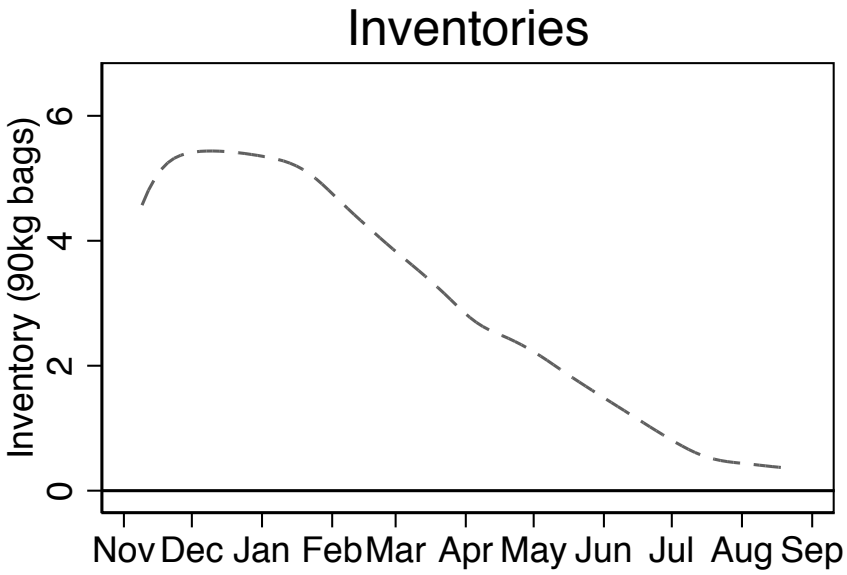
**Sublocation-level randomization**
High intensity = 9 locations
Low intensity = 8 locations

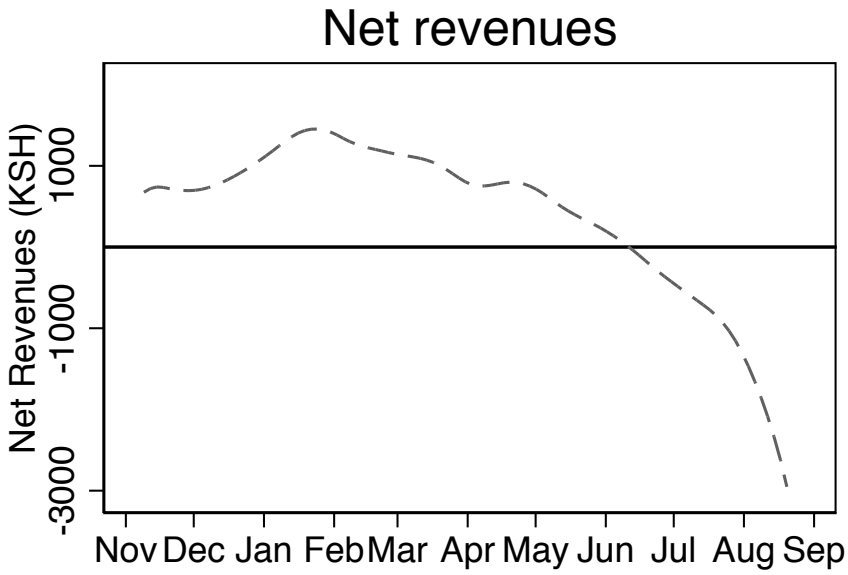
**Group-level randomization**

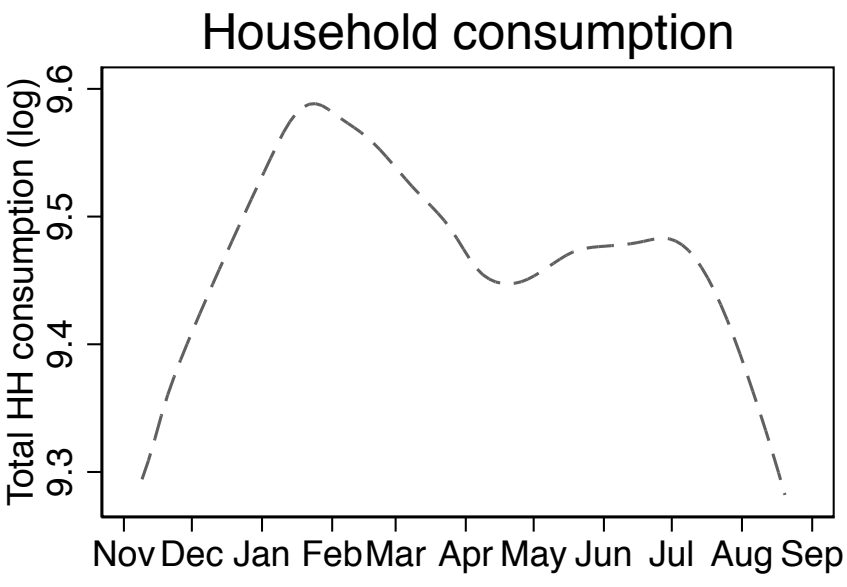



Y1 Y2 Timeline Balance

# Individual Level Effects: Graphical Results



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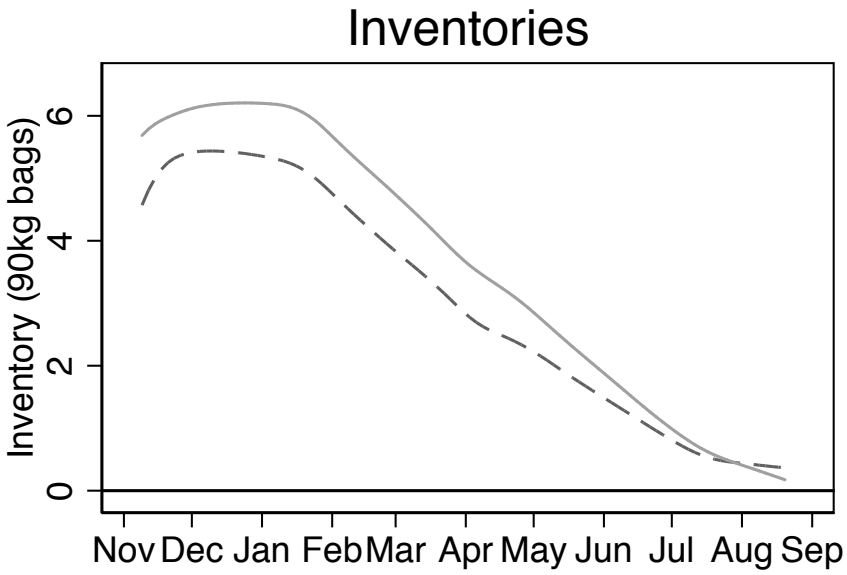


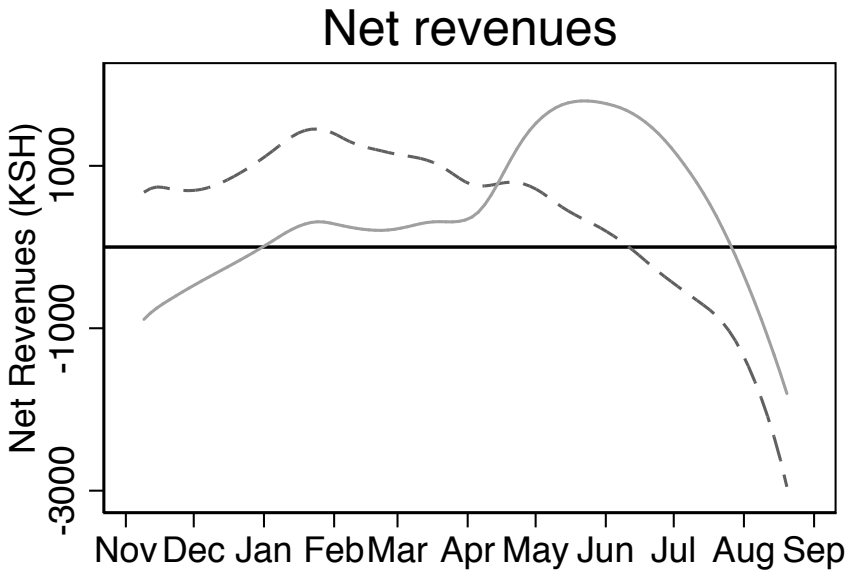


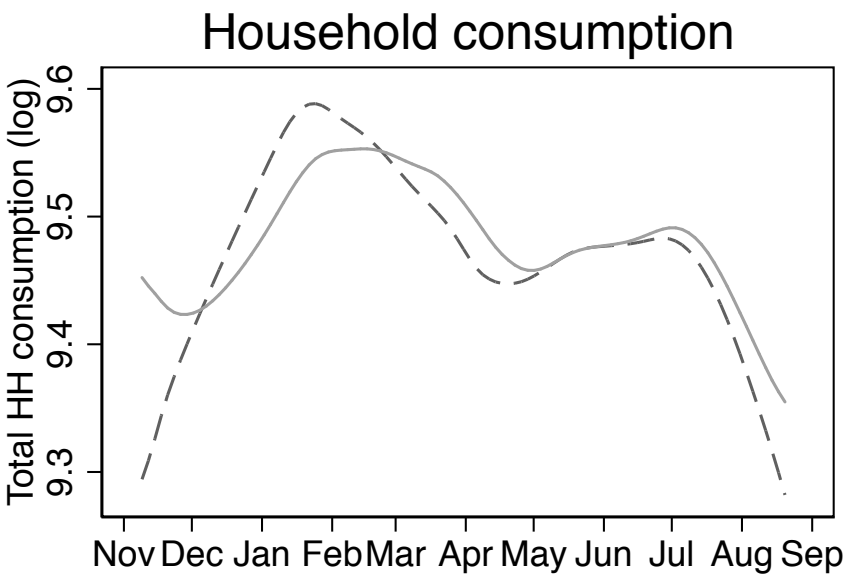

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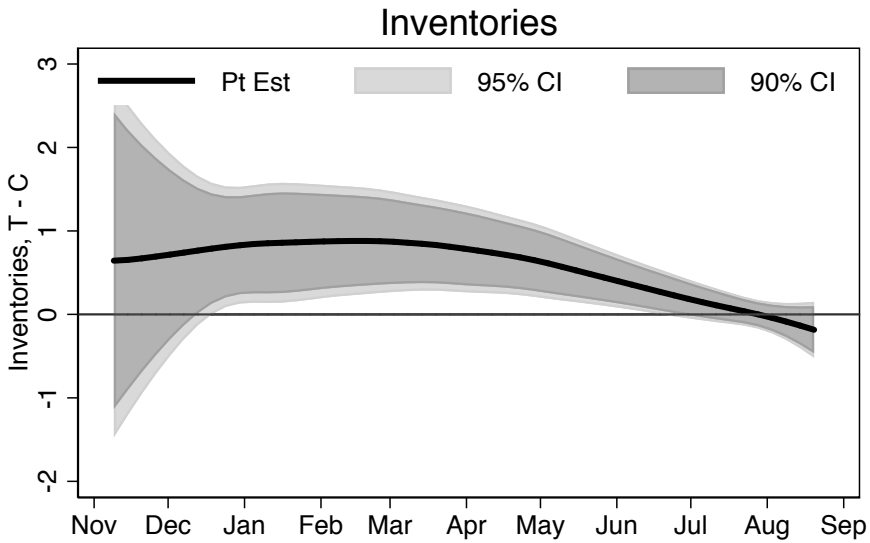


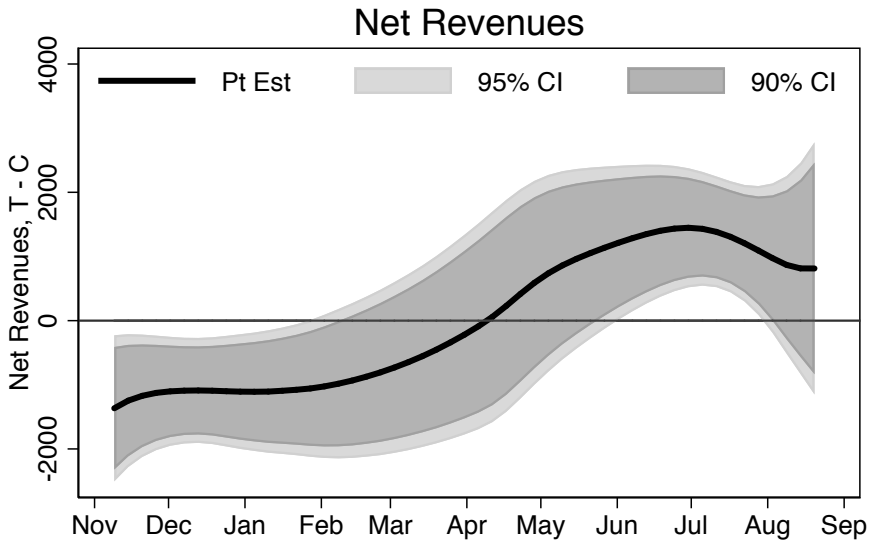


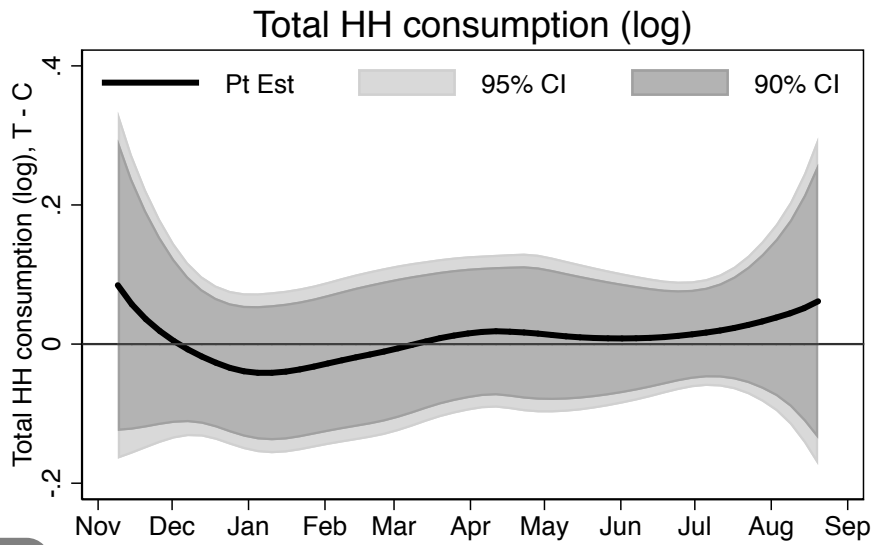


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- Prices will be lower later, as stored maize is released

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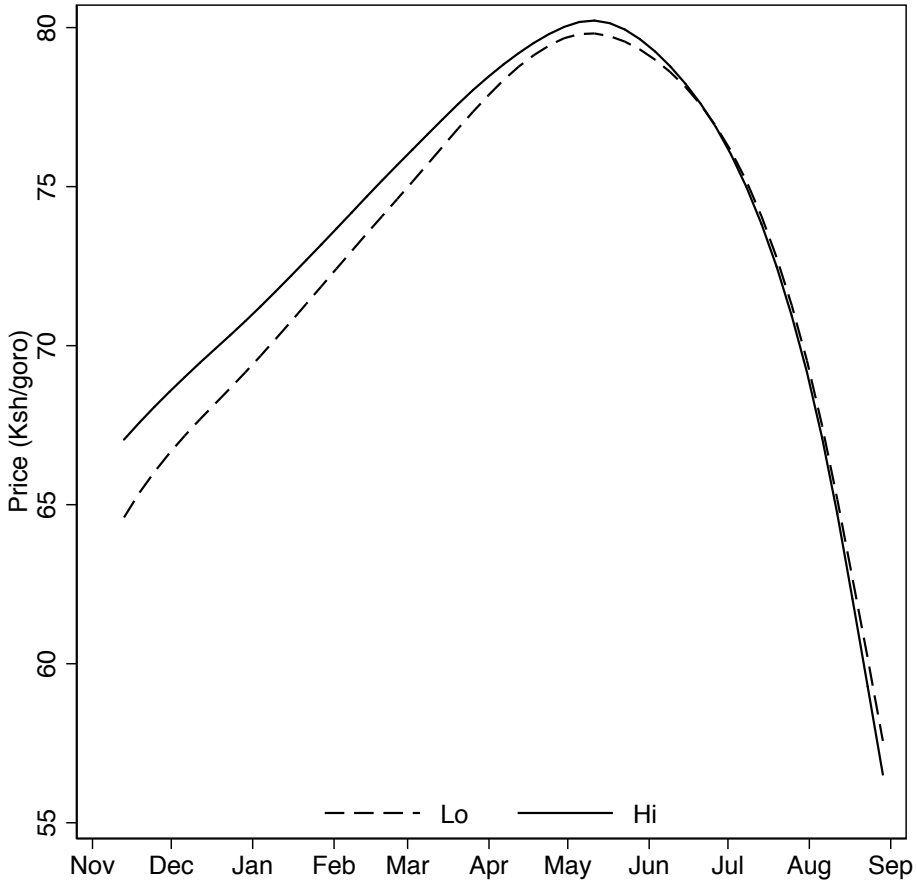


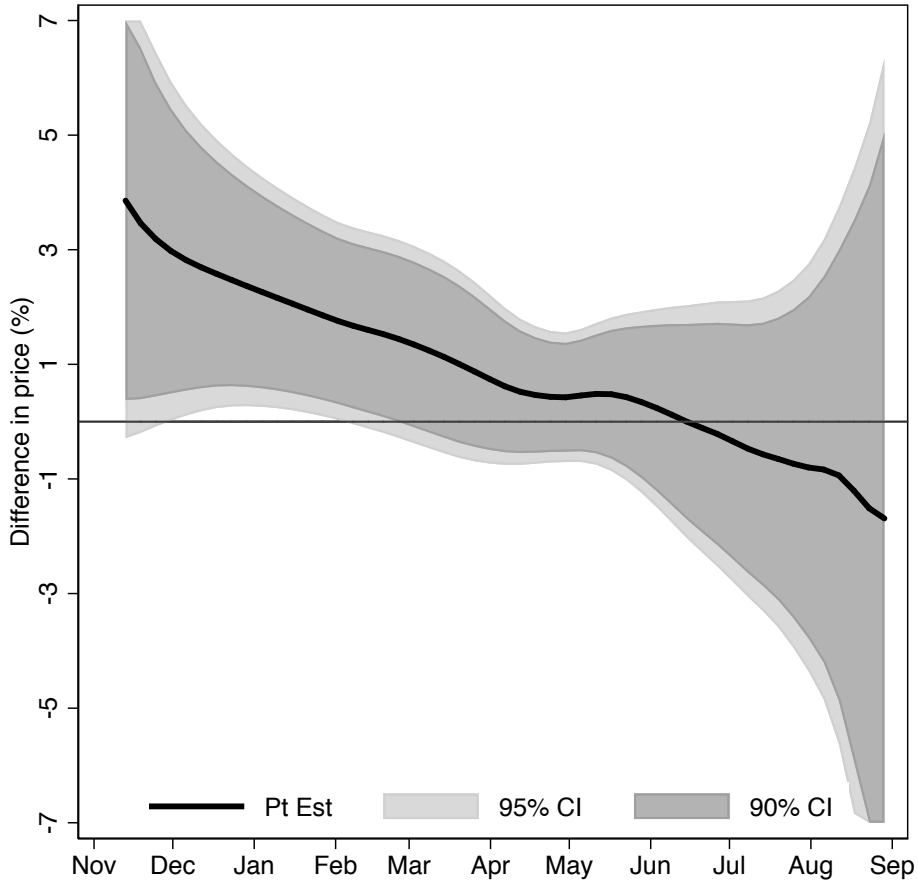


Regression Results  Supply Shift

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- **OAF now scaling the loan to 70,000 farmers in Kenya**

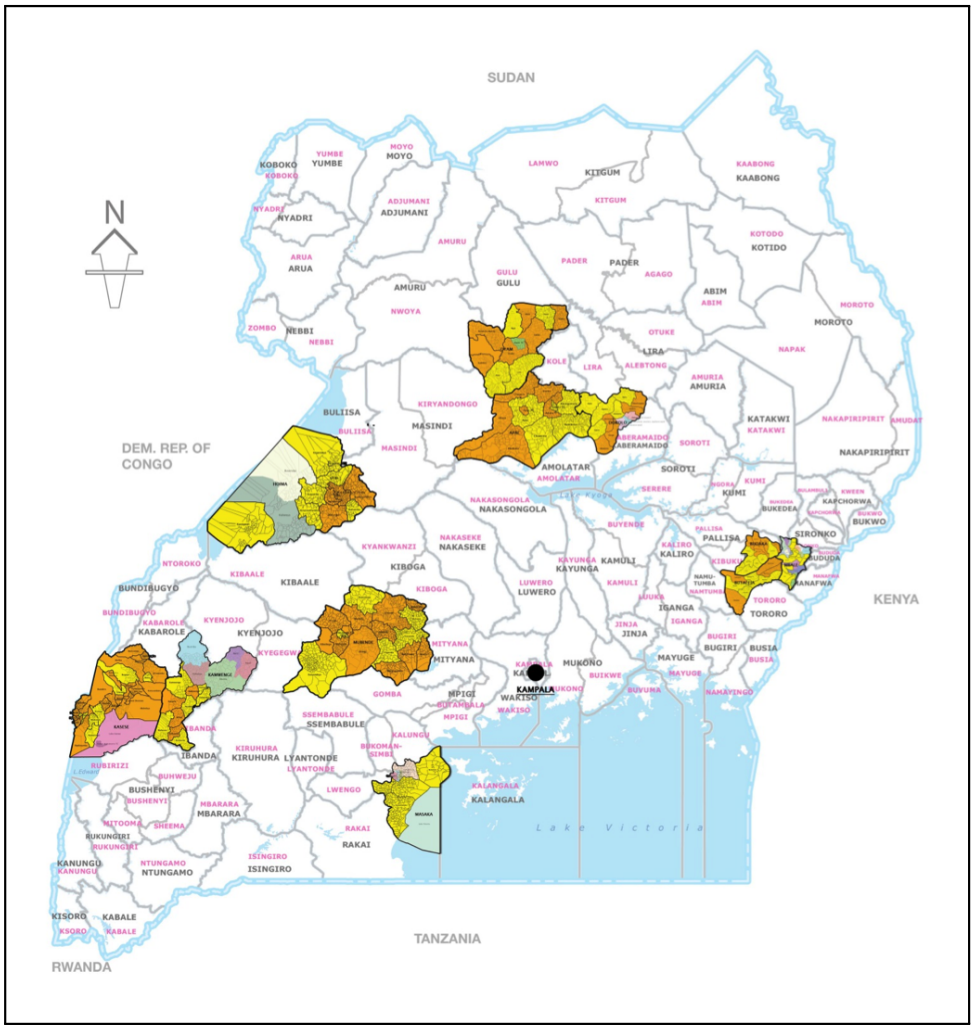
# Project 2: A Mobile-Marketplace for Agriculture

- Kudu: an Alibaba-like marketplace for agriculture trade in Uganda
- Buyers and sellers post quantity, desired price, and location
- Matching algorithm identified specific trades to achieve global optimum, then directly connects buyers and sellers
- Users sent price data via SMS every two weeks

# In-Village Support Services

- AgriNet: one of the largest private sector brokerage firm in Uganda
- Establish in-village agents, who recruit and support farmers & buyers on Kudu
- Agents given access to line of credit to facilitate bulking
- Buyers offered a Transaction Guarantee: AgriNet will reimburse transport costs if quality/quantity not as specified on Kudu

# Study Design

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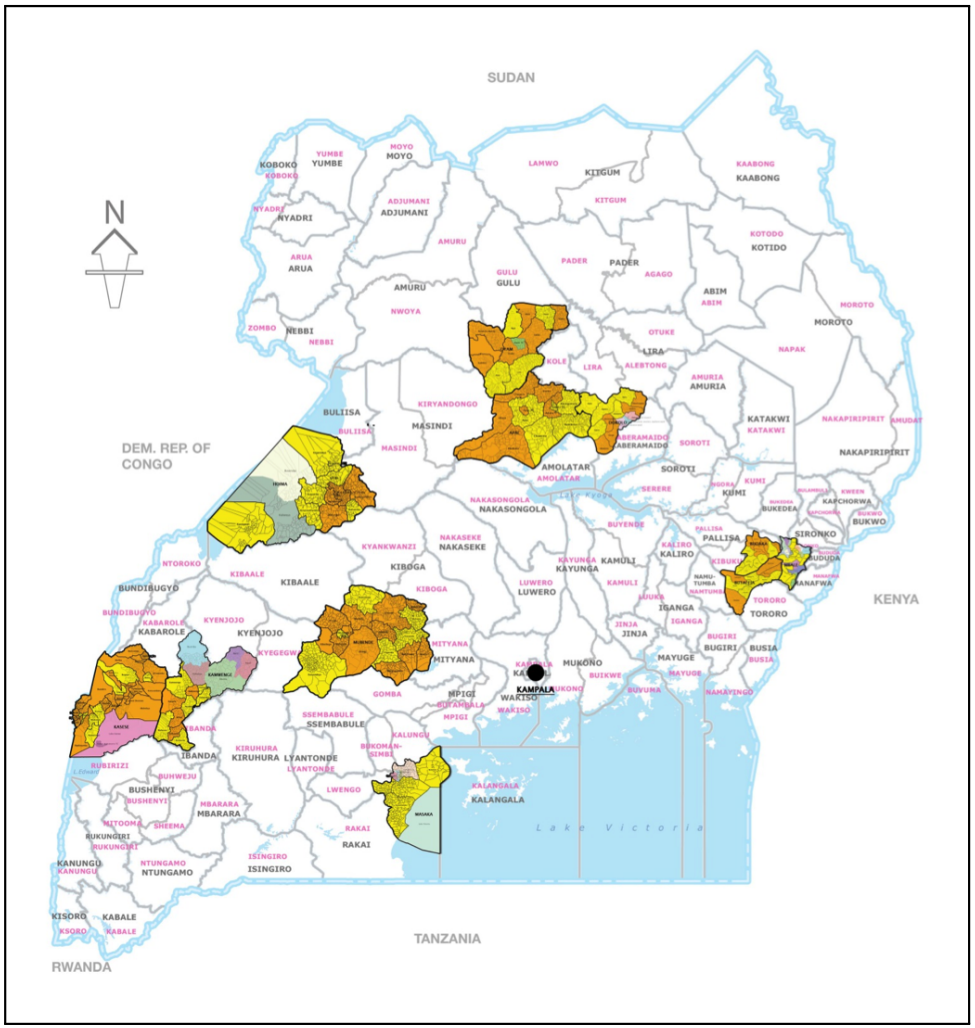


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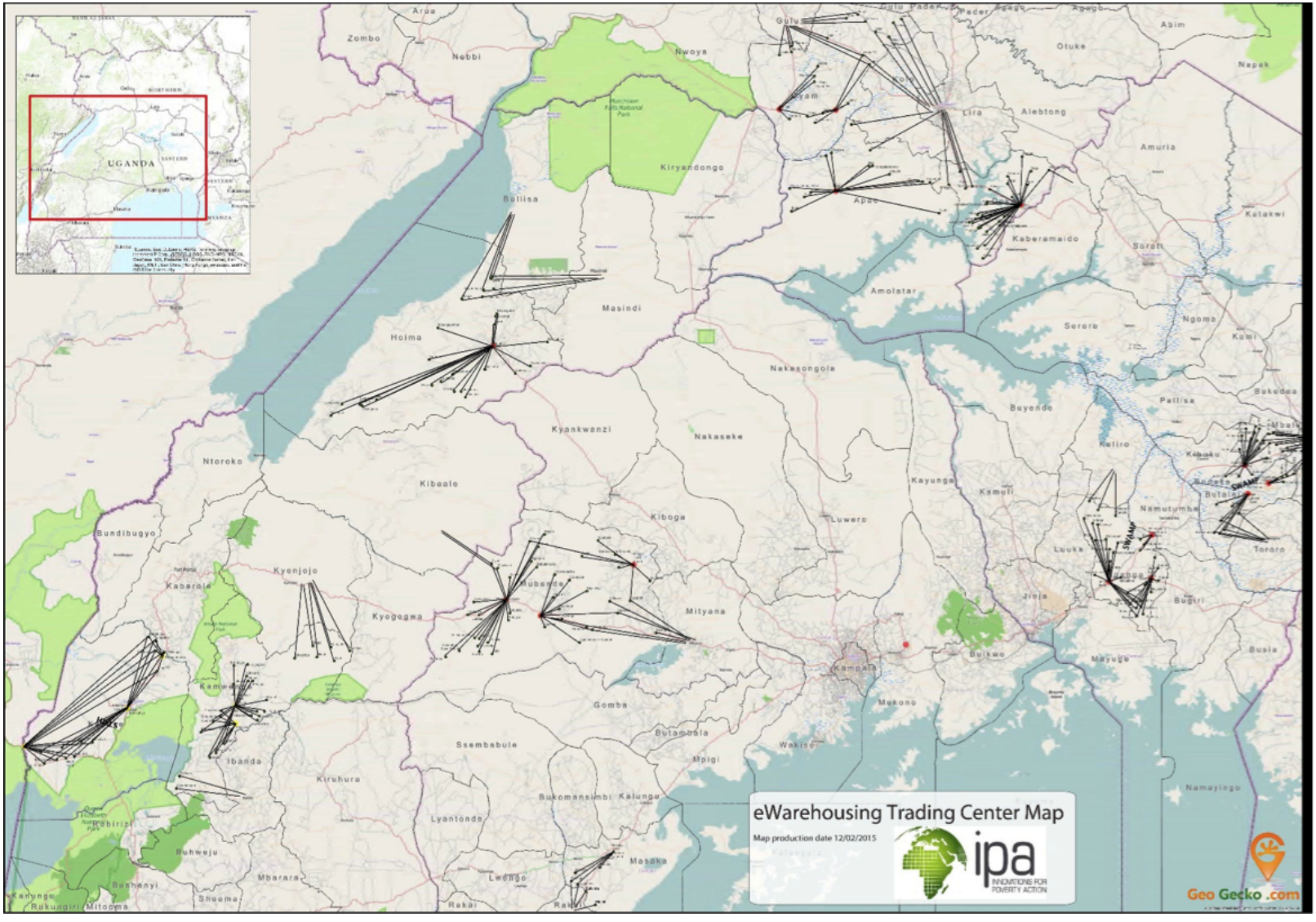
  - Sampling 2-3 largest trading centers in each sub-county
- Household surveys (3,000 HHs)
- Trader surveys (1,400 traders)
- High-frequency price surveys (260 markets)

# Study Markets: Spokes and Hubs

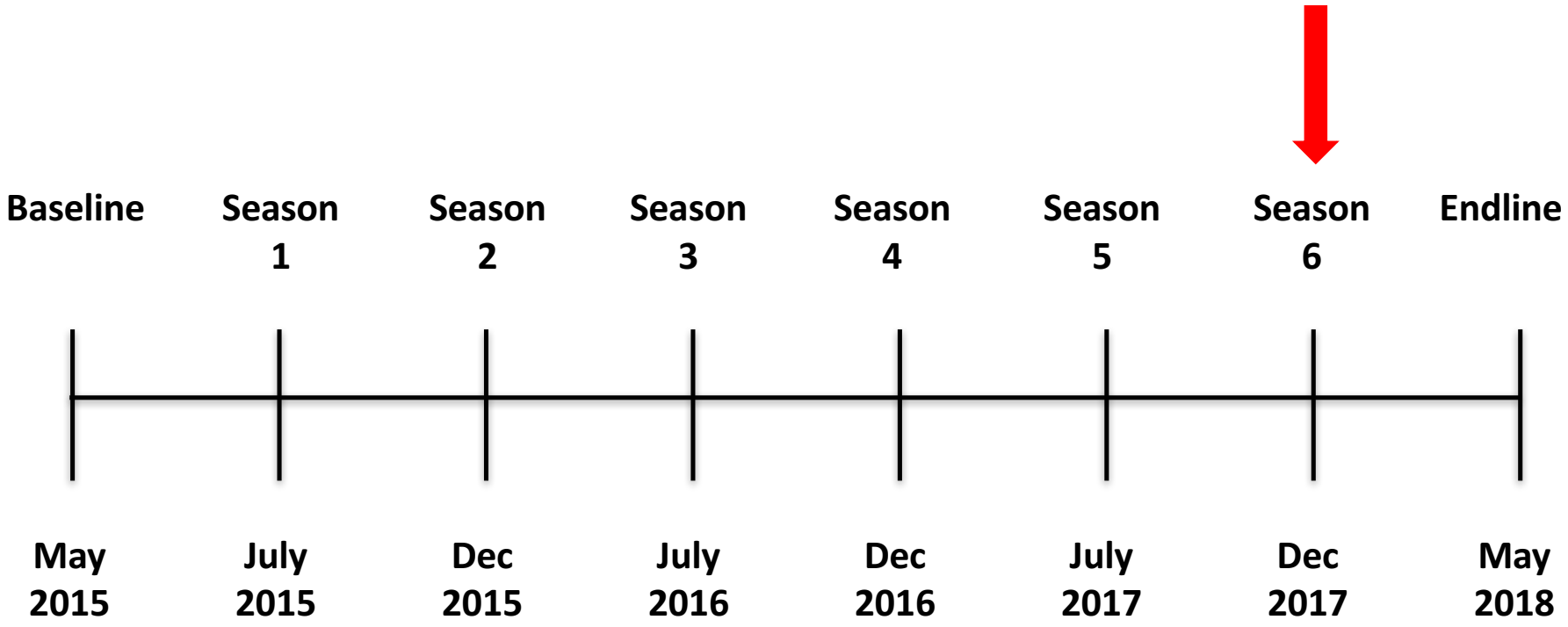


# Sub-Experiments

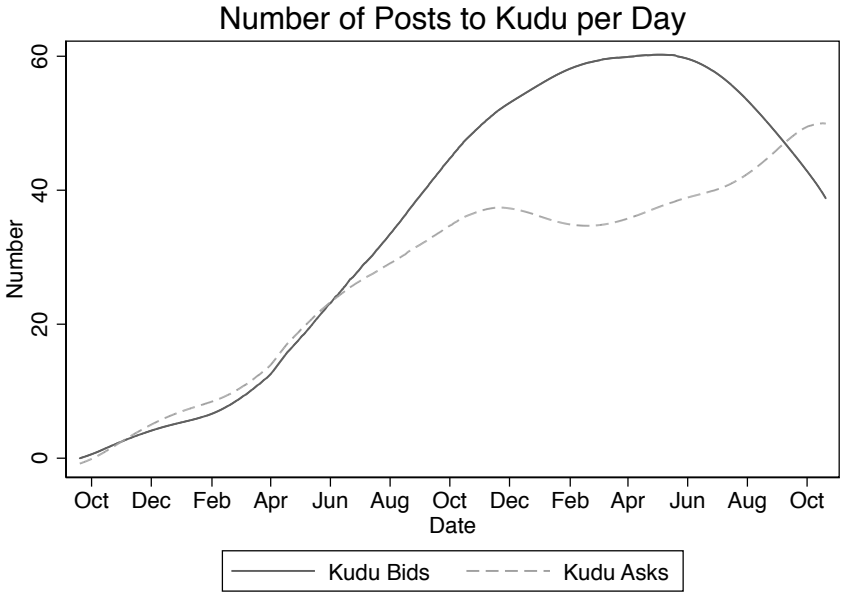
Sub-experiments to test specific constraints:

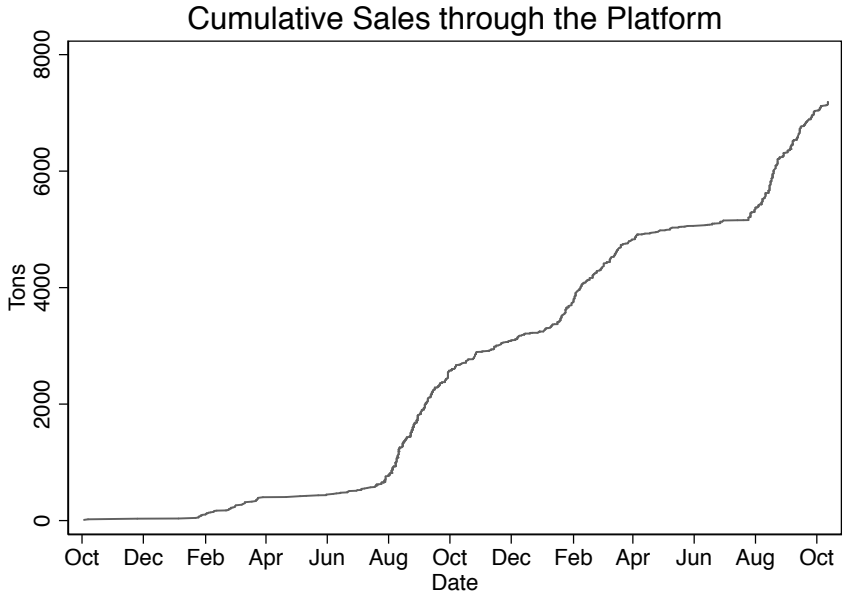
- Search costs:
  - SMS price information sent to a random 75% of households in treated sub-counties
- Credit/aggregation constraints:
  - Access to trading credit randomized at the AgriNet agent level
- Contractual risk:
  - Transaction guarantees randomized at the buyer level

# Project Timeline



# Platform Activity




- Steady growth in bids & asks (except last harvest, when drought dampened supply)
- Sales concentrated during the active parts of the post-harvest season
- **Over $2.2 million USD transacted on the platform so far**

# Initial Results

Results coming next year (after endline):

- Farmer revenue, welfare, and agricultural investment
- Trader search, area of operations, and profits

We can look at preliminary results on market prices and integration

# Initial Results on Price Levels

| | Maize | Beans | Bananas | Tomatos |
|---|---|---|---|---|
| Treated | -12.52 | -5.186 | -69.89 | -5.514 |
| | (17.30) | (38.86) | (605.4) | (6.354) |
| Treated*Hub | 19.03 | -84.03 | 1461.7 | -8.003 |
| | (20.28) | (101.7) | (2365.5) | (14.16) |
| Hub | 20.39 | 117.2 | 992.1 | 15.60 |
| | (15.72) | (83.19) | (1574.1) | (10.02) |
| Mean DV | 914.2 | 2179.2 | 14782.1 | 182.4 |
| N | 8149 | 6167 | 6924 | 8768 |

$\Rightarrow$ No evidence of level effects on prices

# Initial Results on Price Dispersion

| | Maize | Beans | Tomato | Bananas |
|---|---|---|---|---|
| One Market Treated | -0.0643*** | -0.0223 | -0.0886*** | -0.102*** |
| | (0.024) | (0.032) | (0.029) | (0.035) |
| Both Markets Treated | -0.149*** | -0.0184 | -0.133*** | -0.131*** |
| | (0.027) | (0.036) | (0.033) | (0.041) |
| Constant | 1.471*** | 3.841*** | 6.455*** | 5.979*** |
| | (0.046) | (0.049) | (0.055) | (0.060) |
| Observations | 451,521 | 244,610 | 445,400 | 269,502 |
| R-squared | 0.009 | 0.011 | 0.002 | 0.011 |

$\Rightarrow$ Initial evidence from base specification of reductions in price dispersion

# Conclusion

- Barriers to market integration
  - Project 1: Credit constraints reduce integration of markets across time
  - Project 2 (preliminary): Search costs may limit integration of markets across space

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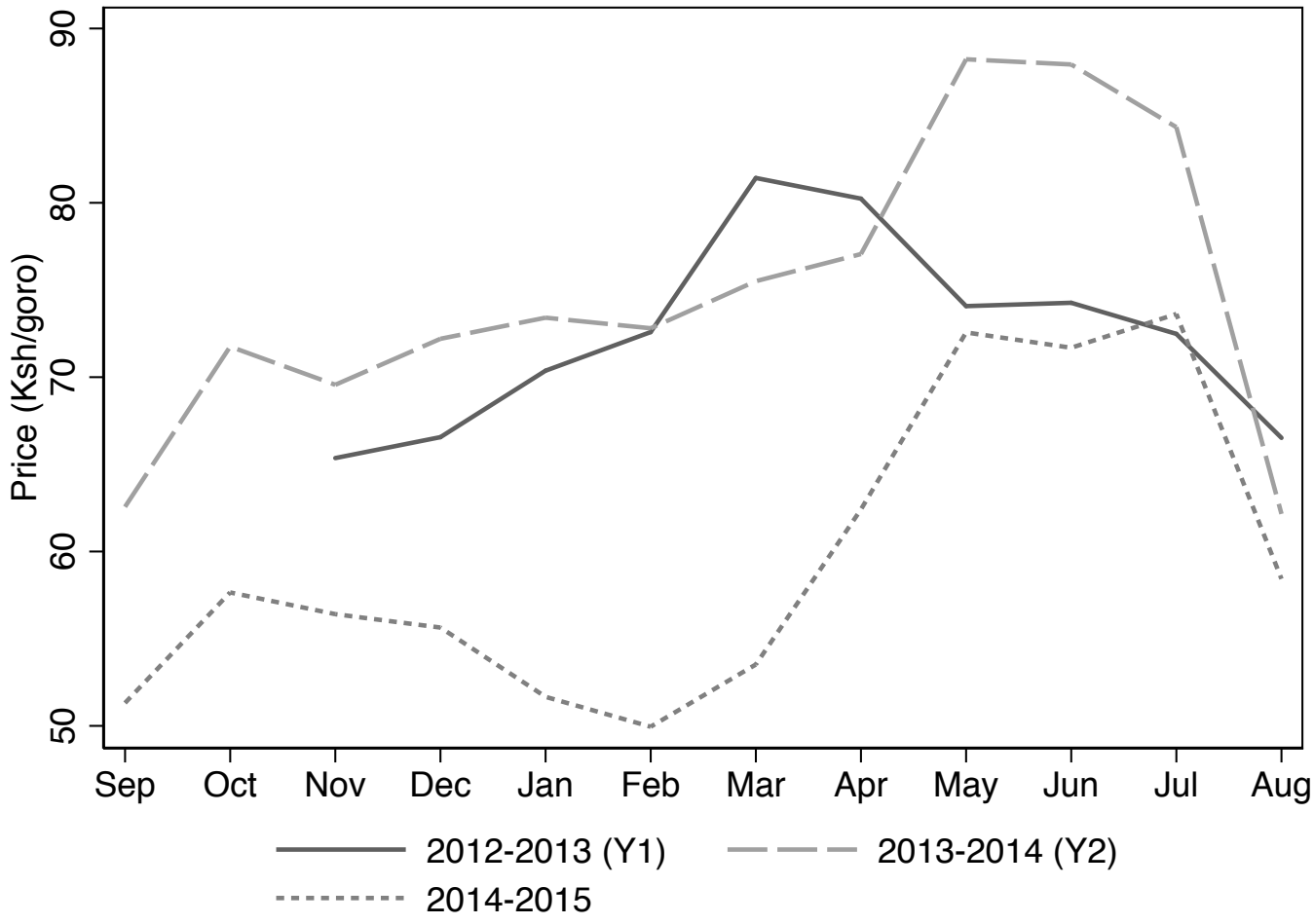
- Barriers to market integration
  - Project 1: Credit constraints reduce integration of markets across time
  - Project 2 (preliminary): Search costs may limit integration of markets across space
- This lack of integration impacts farmer revenue
  - Project 1: Offering farmers harvest-time loans encourages greater storage, higher revenues
- In isolated markets, price response may strongly shape returns
  - Project 1: At scale, lower direct returns to the loan, but substantial indirect returns

# The Setting

Main growing season: harvest in September, prices typically peak around June

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# Other Explanations

1. Storing is not actually profitable
   - But: storage costs are low ($\sim$3.5% of sale price; often already paid)
   - Pest losses appear low ($\sim$2.5% over 6 months)
2. Price risk
   - But: modal households is a net consumer, so price risk aversion should lead to *more precautionary* storage (Park 2006; Saha & Stroud 1994)
   - Moreover, even at lower bound of price increase of 40%, storage still profitable
3. Farmers are impatient
   - But: returns are so high that would require 9-month discount rate $> 33\%$ to justify

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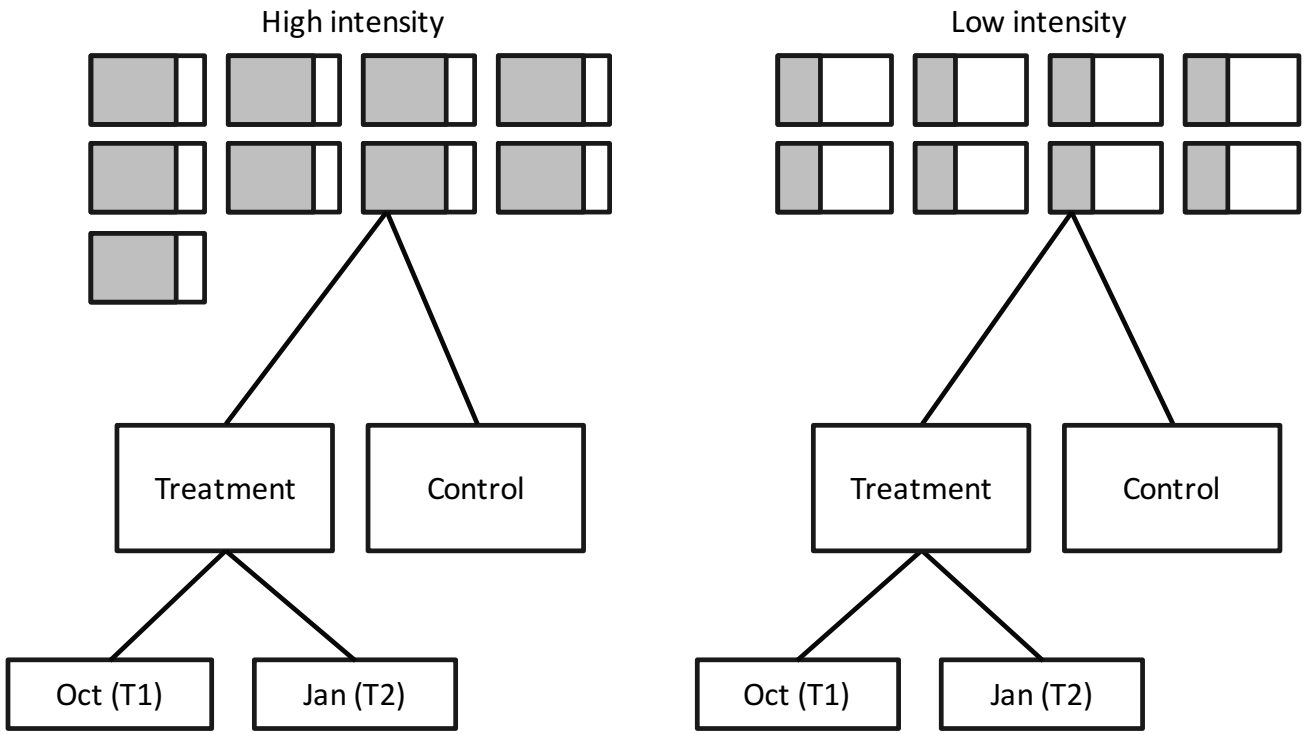
# Experimental Design: Year 1

**Sublocation-level randomization**
High intensity = 9 locations
Low intensity = 8 locations

**Group-level randomization**
T1 = 79 groups
T2 = 80 groups
C = 81 groups

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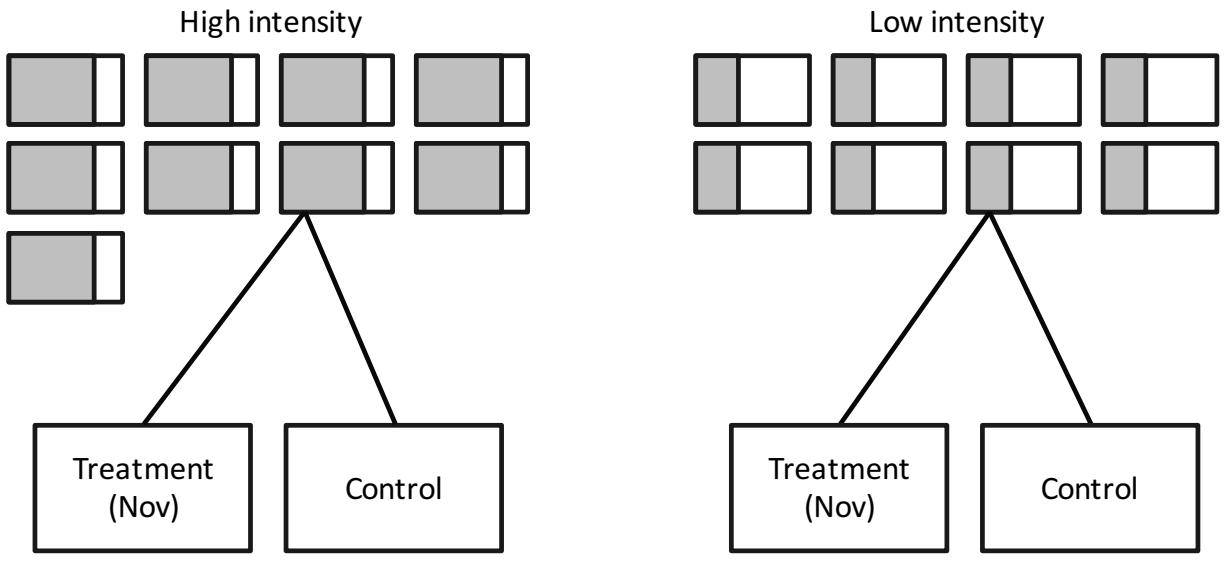
N=1,589

# Experimental Design: Year 2

**Sublocation-level randomization**
High intensity = 9 locations
Low intensity = 8 locations

**Re-randomize:**

**Group-level randomization**
T = 85 groups
C = 86 groups

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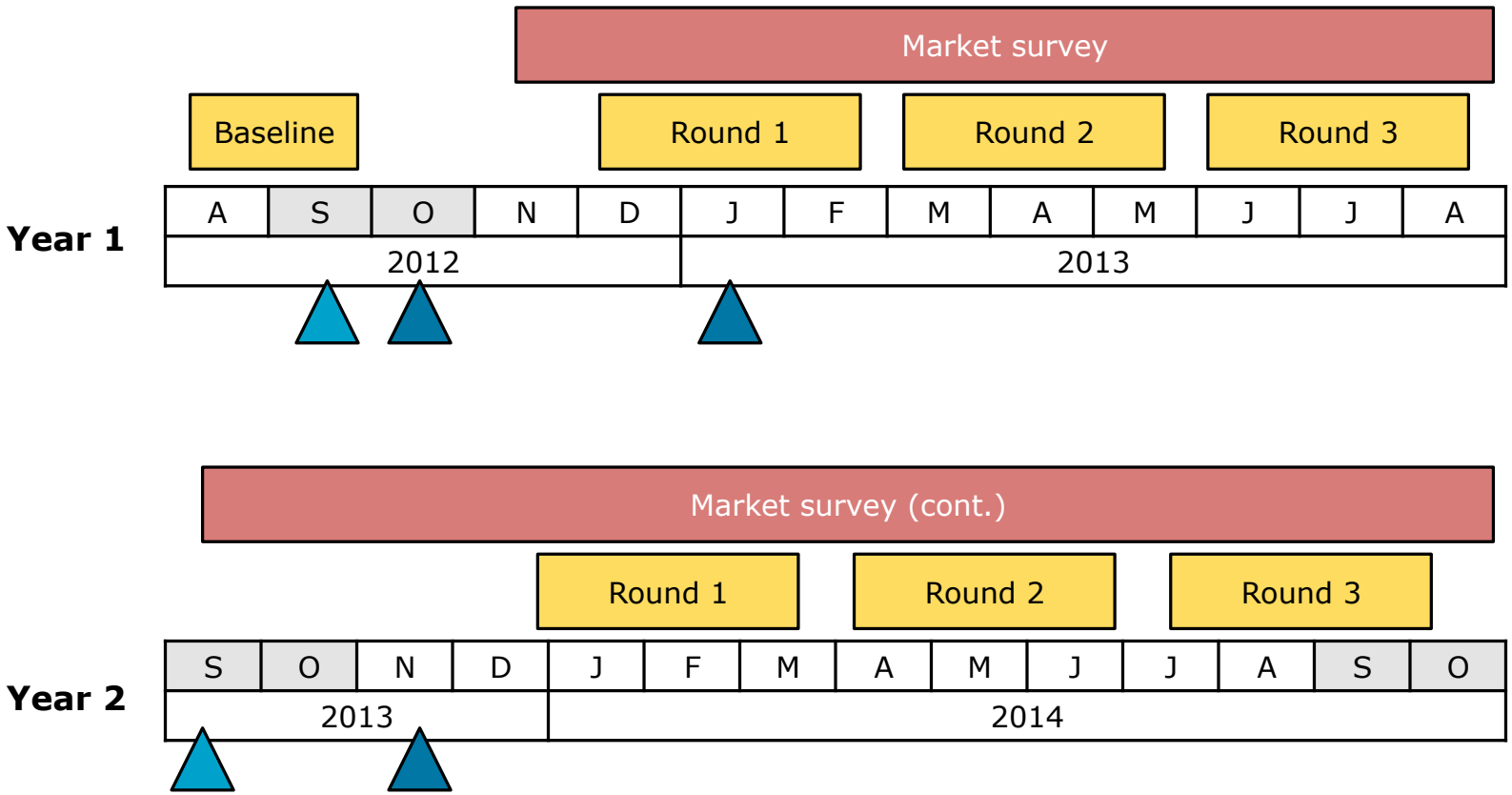


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# Baseline Summary Statistics and Balance

| Baseline characteristic | Control | Treat | Obs | C - T | |
|---|---|---|---|---|---|
| | | | | *sd* | *p-val* |
| Male | 0.33 | 0.30 | 1,589 | 0.08 | 0.11 |
| Number of adults | 3.20 | 3.00 | 1,510 | 0.09 | 0.06 |
| Kids in school | 3.07 | 3.00 | 1,589 | 0.04 | 0.46 |
| Finished primary | 0.77 | 0.72 | 1,490 | 0.13 | 0.02 |
| Finished secondary | 0.27 | 0.25 | 1,490 | 0.04 | 0.46 |
| Total cropland (acres) | 2.40 | 2.44 | 1,512 | -0.01 | 0.79 |
| Number of rooms in hhold | 3.25 | 3.07 | 1,511 | 0.05 | 0.17 |
| Total school fees (1000 Ksh) | 29.81 | 27.24 | 1,589 | 0.06 | 0.18 |
| Average monthly cons (Ksh) | 15,371.38 | 14,970.86 | 1,437 | 0.03 | 0.55 |
| Avg monthly cons./cap (log Ksh) | 7.96 | 7.97 | 1,434 | -0.02 | 0.72 |
| Total cash savings (KSH) | 8,021.50 | 5,157.40 | 1,572 | 0.09 | 0.01 |
| Total cash savings (trim) | 5,389.84 | 4,731.62 | 1,572 | 0.05 | 0.33 |
| Has bank savings acct | 0.43 | 0.42 | 1,589 | 0.01 | 0.82 |
| Taken bank loan | 0.08 | 0.08 | 1,589 | 0.02 | 0.73 |
| Taken informal loan | 0.25 | 0.24 | 1,589 | 0.01 | 0.84 |
| Liquid wealth | 97,280.92 | 93,878.93 | 1,491 | 0.03 | 0.55 |
| Off-farm wages (Ksh) | 3,797.48 | 3,916.82 | 1,589 | -0.01 | 0.85 |
| Business profit (Ksh) | 1,801.69 | 2,302.59 | 1,589 | -0.08 | 0.32 |
| Avg $\%\Delta$ price Sep-Jun | 133.18 | 133.49 | 1,504 | -0.00 | 0.94 |
| Expect 2011 LR harvest (bags) | 9.03 | 9.36 | 1,511 | -0.02 | 0.67 |
| Net revenue 2011 | -4,088.62 | -3,303.69 | 1,428 | -0.03 | 0.75 |
| Net seller 2011 | 0.30 | 0.32 | 1,428 | -0.05 | 0.39 |
| Autarkic 2011 | 0.06 | 0.07 | 1,589 | -0.03 | 0.51 |
| % maize lost 2011 | 0.01 | 0.02 | 1,428 | -0.03 | 0.57 |
| 2012 LR harvest (bags) | 11.03 | 11.18 | 1,484 | -0.02 | 0.74 |
| Calculated interest correctly | 0.73 | 0.71 | 1,580 | 0.03 | 0.50 |
| Digit span recall | 4.58 | 4.57 | 1,504 | 0.01 | 0.89 |
| Maize giver | 0.26 | 0.26 | 1,589 | 0.00 | 0.99 |

Back

# Individual Level Effects: Regression Results

| | Inventory | | Net Revenues | | Consumption | |
|---|---|---|---|---|---|---|
| | Overall | By rd | Overall | By rd | Overall | By rd |
| Treat | 0.53*** | | 524.66** | | 0.04 | |
| | (0.12) | | (220.25) | | (0.03) | |
| Treat - R1 | | 1.03*** | | -608.68** | | 0.01 |
| | | (0.20) | | (285.70) | | (0.03) |
| Treat - R2 | | 0.52*** | | 1170.71*** | | 0.05 |
| | | (0.12) | | (359.84) | | (0.03) |
| Treat - R3 | | 0.07 | | 985.79*** | | 0.04 |
| | | (0.19) | | (302.09) | | (0.03) |
| Observations | 6780 | 6780 | 6730 | 6730 | 6736 | 6736 |
| Mean DV | 2.16 | 2.16 | -1616.12 | -1616.12 | 9.55 | 9.55 |
| R squared | 0.29 | 0.30 | 0.09 | 0.09 | 0.02 | 0.02 |

Specification Other Results Back

# Individual Level Effects: Regression Estimation

The "Intent To Treat" effect of being offered the loan, pooled across rounds:

$$Y_{ijry} = \alpha + \beta T_{jy} + \eta_{ry} + \varepsilon_{ijry}$$

- $Y_{ijry} =$ outcome for farmer $i$ in group $j$ in round $r$ in year $y$
- $T_{jy} =$ treatment status of group $j$ in year $y$
- $\eta_{ry} =$ round x year fixed effects
- SE clustered by group

And separately by round:

$$Y_{ijry} = \alpha + \sum_{r=1}^{3} \beta_r T_{jy} + \eta_{ry} + \varepsilon_{ijry}$$

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# Individual Level Effects: Other Effects

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- Does greater access to output markets encourage invest in inputs?

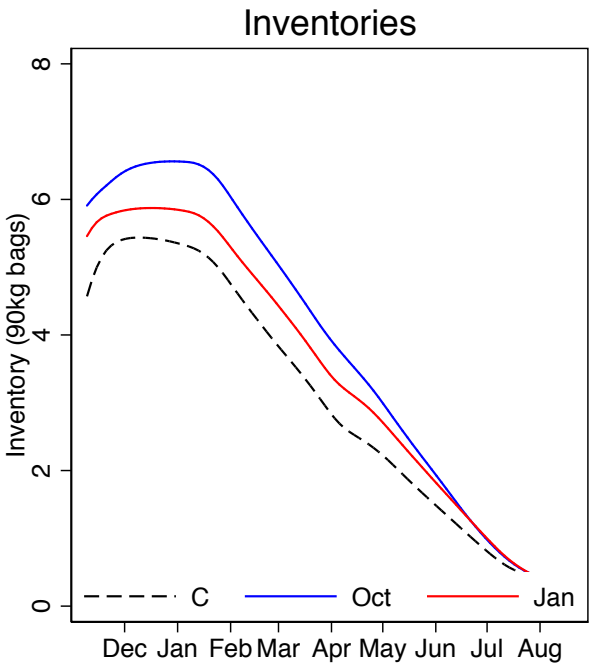
  $\Rightarrow$ Not in this context: No evidence of long-run effect on farm input use or harvest levels More

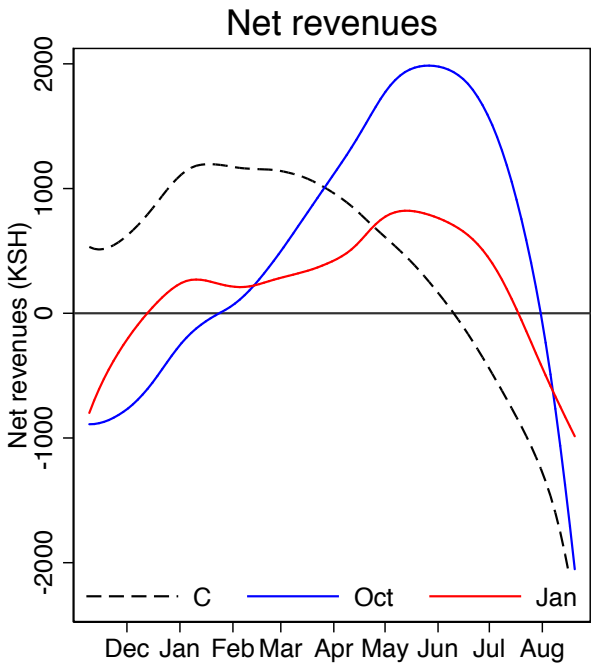
- Can a one-time infusion stimulate saving one's way out of constraint?

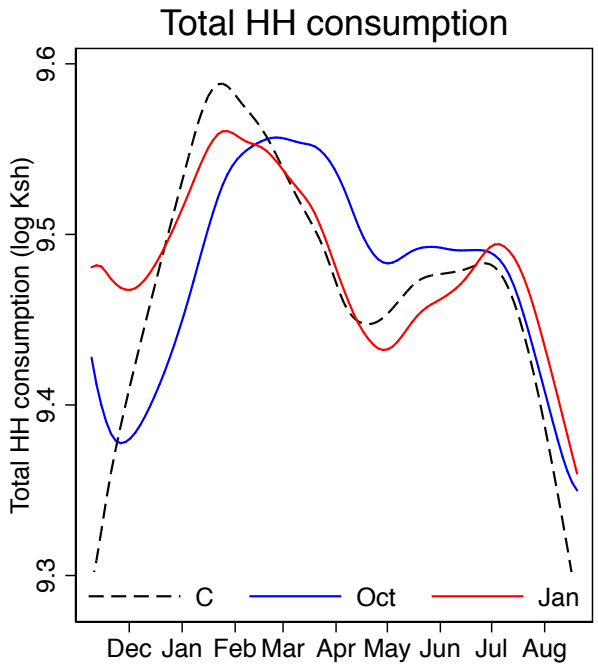
  $\Rightarrow$ Non-definitive evidence: No evidence of long-run effect on timing of sales; noisy, but potentially large revenue effects More

Back

# Loan Timing Matters

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# Effect on Inputs and Harvest Levels

| | Days Labor | | Non-Labor Input Exp | | 2015 Harvest | |
|---|---|---|---|---|---|---|
| | Y1 | Y2 | Y1 | Y2 | Y1 | Y2 |
| Treat Y1 | -4.76 | | 18.46 | | -0.22 | |
| | (5.98) | | (213.39) | | (0.56) | |
| Treat Y2 | | -9.66 | | 122.23 | | 0.92 |
| | | (7.04) | | (194.98) | | (0.59) |
| Observations | 979 | 940 | 978 | 940 | 987 | 946 |
| R squared | 0.01 | 0.00 | 0.01 | 0.00 | 0.00 | 0.00 |
| Mean DV Control | 126.15 | 131.48 | 2620.61 | 2271.07 | 9.78 | 9.97 |

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# Long Run Effect on Sales and Revenues

| | % Lean Sales | | % Harvest Purch | | Revenues | |
|---|---|---|---|---|---|---|
| Treat Y1 | 0.04 | | -0.02 | | 350.50 | |
| | (0.05) | | (0.03) | | (950.10) | |
| Treat Y2 | | -0.03 | | -0.03 | | 1286.62 |
| | | (0.04) | | (0.04) | | (1094.42) |
| Observations | 532 | 534 | 724 | 665 | 979 | 938 |
| R squared | 0.00 | 0.01 | 0.02 | 0.00 | 0.00 | 0.00 |

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# Market Effects: Estimation

We estimate:

$$P_{mst} = \alpha + \beta_1 Hi_s + \beta_2 month_t + \beta_3 (Hi_s * month_t) + X_m + \varepsilon_{mst}$$

- $P_{mst}$ = price in market $m$ in sublocation $s$ in month $t$
- $Hi_s$ = 1 in high-density areas
- $X_m =$ controls (distance to nearest road)
- SE clustered at sublocation (additional corrections for small num clusters)

Prediction: $\beta_1 > 0$, $\beta_3 < 0$

# Market Effects: Regression Results

| | Y1 | Y2 | Pooled |
|---|---|---|---|
| Hi | 4.41* | 2.85 | 3.97** |
| | (2.09) | (1.99) | (1.82) |
| Month | 1.19*** | 1.22*** | 1.36*** |
| | (0.36) | (0.38) | (0.35) |
| Hi Intensity * Month | -0.57 | -0.48 | -0.57 |
| | (0.42) | (0.46) | (0.39) |
| Observations | 491 | 381 | 872 |
| R squared | 0.08 | 0.03 | 0.06 |

Randomization inference

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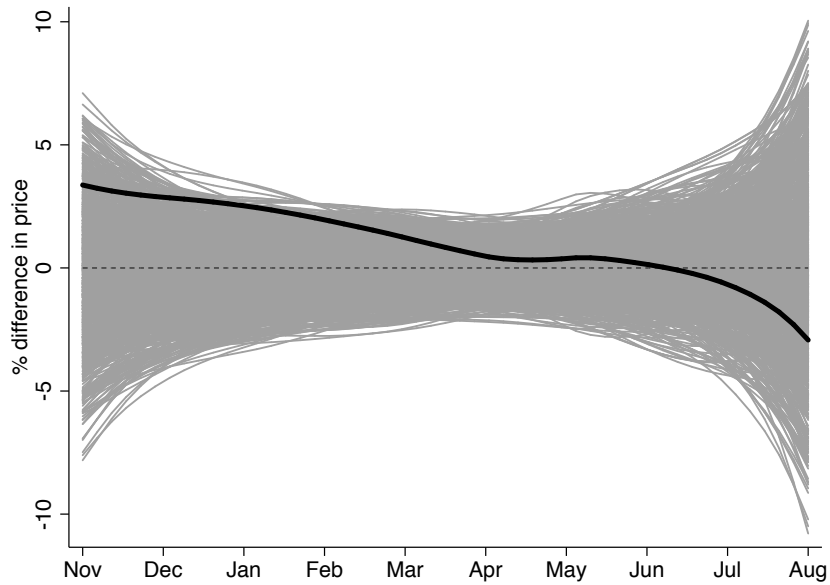
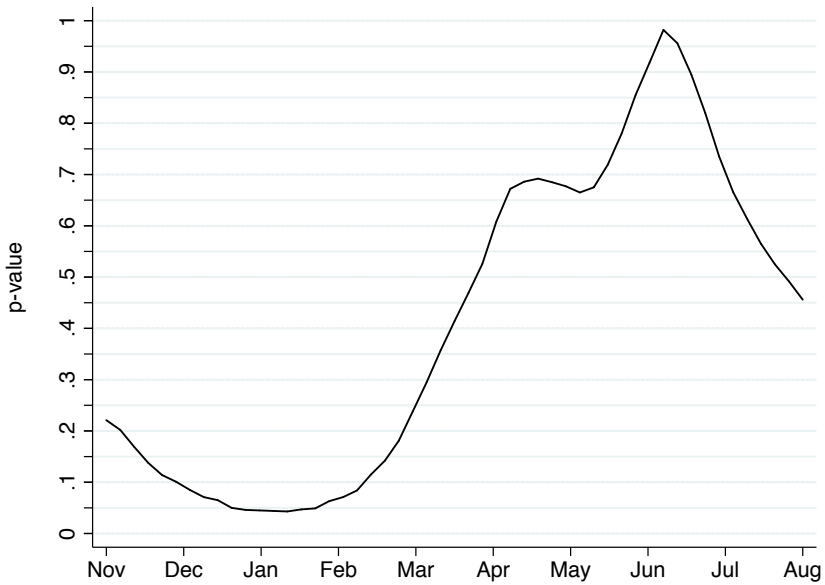
# Market Effects: Nonparametric Randomization Inference

Treatment Effects under 1,000 Placebo Treatment Assignments




Randomization-Inference P-values

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# Market Effects: Implications

We saw a 2.5% increase in prices at harvest time. Does the size of this effect make sense, given the induced shift in supply?

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$$\%\Delta q_t = \underbrace{0.30}_{\text{OAF density}} * \underbrace{0.40}_{\text{treatment density}} * \underbrace{0.58}_{\text{\% Treat}} * \underbrace{-0.48}_{\hat{\beta}_{1\,sales}} = -3.3\%$$

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Note: detectable price effects are a further indication that markets are isolated. The above assumes no trade

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# Treatment Spillovers

$$Y_{ijry} = \alpha + \beta_1 T_{jy} + \beta_2 Hi_s + \beta_3 T_{jy} * Hi_s + \eta_{ry} + \varepsilon_{ijry}$$

| | (1) Inventory | (2) Net Revenues | (3) Consumption |
|---|---|---|---|
| Treat | 0.74*** | 1101.39** | -0.01 |
| | (0.15) | (430.09) | (0.02) |
| Hi | 0.02 | 164.94 | -0.05 |
| | (0.24) | (479.68) | (0.04) |
| Treat * Hi | -0.29 | -816.77 | 0.07* |
| | (0.19) | (520.04) | (0.04) |
| Observations | 6780 | 6730 | 6736 |
| Mean DV | 2.59 | -1055.15 | 9.54 |
| R squared | 0.29 | 0.09 | 0.03 |
| p-val T+TH=0 | 0.01 | 0.41 | 0.08 |

Effects by year Back

# Treatment Spillovers by Year

| | Inventory | | Net Revenues | | Consumption | |
|---|---|---|---|---|---|---|
| | Y1 | Y2 | Y1 | Y2 | Y1 | Y2 |
| Treat | 0.76*** | 0.55*** | 1059.60** | 1193.77 | 0.01 | -0.05 |
| | (0.19) | (0.18) | (437.73) | (685.05) | (0.04) | (0.04) |
| Hi | 0.12 | -0.03 | 533.90 | -152.60 | -0.00 | -0.08 |
| | (0.36) | (0.22) | (551.18) | (558.95) | (0.05) | (0.05) |
| Treat*Hi | -0.33 | -0.07 | -1114.63* | -555.21 | -0.01 | 0.17*** |
| | (0.23) | (0.25) | (535.59) | (804.86) | (0.05) | (0.06) |
| Observations | 3836 | 2944 | 3795 | 2935 | 3792 | 2944 |
| Mean DV | 2.74 | 1.38 | -253.51 | -3620.40 | 9.47 | 9.65 |
| R squared | 0.35 | 0.18 | 0.01 | 0.04 | 0.00 | 0.02 |
| p-val T+TH=0 | 0.01 | 0.02 | 0.86 | 0.15 | 0.97 | 0.01 |

Back

# How do GE Effects Shape the Distribution of Gains?

$$Revenue_{ijry} = \alpha + \beta_1 T_{jy} + \beta_2 Hi_s + \beta_3 T_{jy} * Hi_s + \eta_{ry} + \varepsilon_{ijry}$$

| | Low Sat | High Sat |
|---|---|---|
| **1. Direct gains/person** | 3,304 | 854 |
| **2. Indirect gains/person** | 0 | 495 |
| **3. Ratio of indirect: direct gains** | 0.00 | 0.58 |
| **4. Direct beneficiary population** | 247 | 495 |
| **5. Total population** | 3,553 | 3,553 |
| **6. Total direct gains** | 816,984 | 422,248 |
| **7. Total indirect gains** | 0 | 1,757,880 |
| **8. Total gains (direct + indirect)** | 816,984 | 2,180,128 |
| **9. Fraction of gains indirect** | 0.00 | 0.81 |
| **10. Private gains/person** | 3,304 | 1,349 |
| **11. Total private gains** | 816,984 | 666,945 |
| **12. Fraction of gains private** | 1.00 | 0.31 |

Assumptions Back

# Gains Distribution Assumptions

Calculations employ coefficient $\beta_1, \beta_2$, and $\beta_3$ on revenues (x3 to annualize):

- Direct benefits: $\beta_1$ (for low treated) and $\beta_1 + \beta_2$ (for high treated)
- Indirect benefits: $\beta_3$ (for treated and untreated in low)
- Private benefits $\beta_1$ (for low treated) and $\beta_1 + \beta_2 + \beta_3$ (for high treated)

Additional assumptions:

- Total population in the study area = 7,105
- 50% of the study population resides in low saturation sublocations
- 30% of farmers in the region are One Acre Fund (OAF) members
- 40% of all OAF members were enrolled in the study in low saturation sublocations and 80% in high
- In each sublocation, 58% of individuals in the sample were randomly assigned to receive treatment

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