Technology Adoption: Understanding Heterogeneity

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Heterogeneity

Hard to think that agricultural technologies have the same returns across any given population of farmers

We know that average returns to agricultural technologies such as hybrid maize and fertilizer can be extremely high, on the order of 100%

If you are a farmer, using these technologies can double your profits from maize!

Is that true for all farmers?

How About These Farmers?

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And These Farmers?

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And These?

Understanding Heterogeneity

Can heterogeneity in the benefits (and costs) of technologies explain one of the main puzzles that we see all over Africa, i.e. that

i. Despite high average returns, a significant number of households do not use these technologies: why not?

ii. Adoption rates show no acceleration/increases over time

The answer turns out to be yes!

Outline

Motivating the puzzle and how heteroegeneity can account for this puzzle

Model of technology adoption with heteroegeneity

Estimating the model

Correlate the estimated returns w/ adoption: does heterogeneity in costs and benefits explain adoption and lack of adoption?

What is My Hypothesis?

Are there are differences in returns to the technology across farmers?

If so, is it simply the case that the farmers who do not use it simply do not benefit from it?

Is the lack of adoption explained by zero or negative returns to the technology?

Why is This Important?

Country	Crop (Hg/Ha)	1961-70	1971-80	1981-90	1991-04
Kenya	**Maize**	**0.362**	**2.373**	**1.169**	**-1.198**
India	Wheat	4.876	2.514	3.343	1.235
India	Rice	0.954	1.714	3.310	0.838
Mexico	Maize	2.057	4.267	-0.548	1.447
Zambia	Maize	-0.267	10.40	1.571	-1.707

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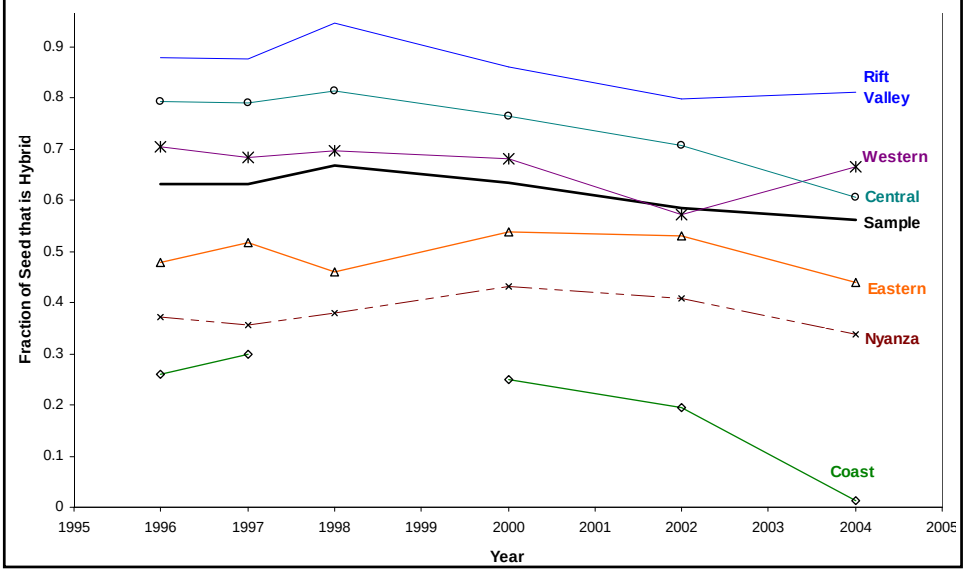
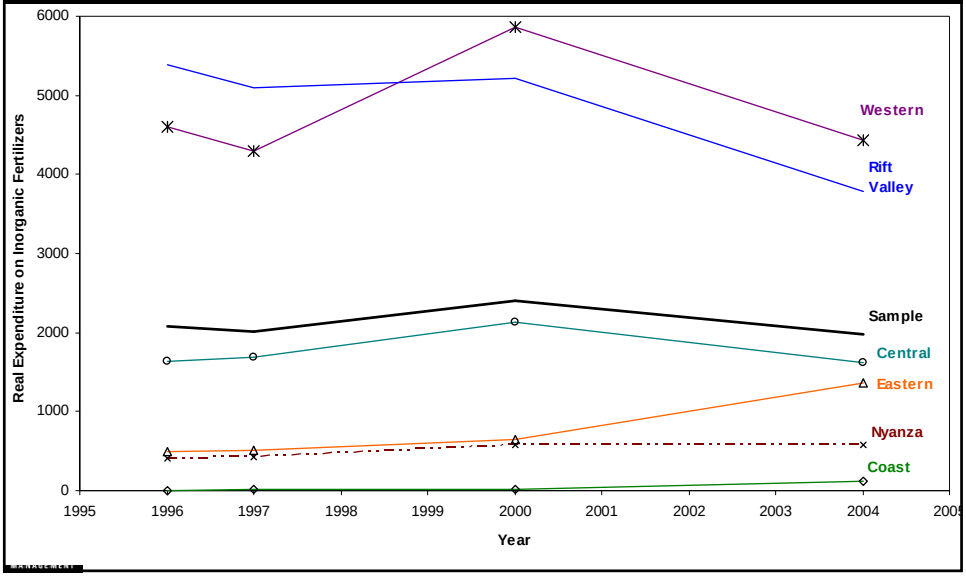
Hybrid Adoption



Fertilizer Adoption (Province)



What About the Farmers?

Priorities to Improve Family Well Being	HHs for whom it is the Top Priority	HHs that Place it in the Top 3 Priorities
Increase Yields on Existing Land	39.4%	72.7%
Obtain More Land	16.4%	29.2%
Obtain More Animals	14.5%	55.4%
Start a Business/ Earn more from Business	23.2%	48.4%
Education	2.3%	5.9%
Credit	0.3%	0.5%

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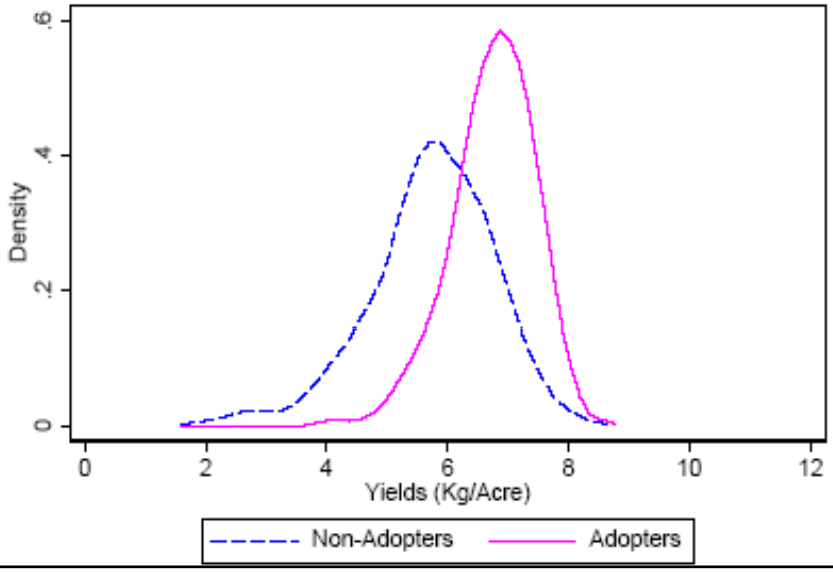
Yields by Sector, 2004



How Do I Test My Hypothesis

What Do I Do?

I start with an economic model of how households make decisions about which technology to use

Adoption Decisions I

Model is based on a generalized Roy model of sector (technology) choice

Allows for two forms of household specific heterogeneity:

- Absolute advantage (not correlated with the technology choice)
- Comparative advantage (relative productivity in hybrid over non-hybrid)

Adoption Decisions II

A farmer will adopt hybrid if his profits from hybrid are greater than his profits from non hybrid

Allow directly for the following:

- Different quantities of fertilizer to be used
- Fixed (over time) costs of access
- Time varying costs of access

Prices of the two seeds are different, but not much spatial variation in this price difference

Adoption Decisions III

This is basically a model of comparative advantage that finally gives me:

A farmer will adopt if $\phi\theta_i > A_{it} + \Delta^s_{it} - (\beta^H_t - \beta^N_t)$

The parameter ϕ tells us …

Adoption Decisions IV

Implies a production function for maize of the following form:

$$y_{it} = \beta_t^N + \alpha_i + (\beta_t^H - \beta_t^N)h_{it} + X_{it}'\gamma^N + \phi\theta_i h_{it} + X_{it}'(\gamma^H - \gamma^N)h_{it} + \varepsilon_{it}$$

Interpretation

$$y_{it} = \pi + \beta h_{it} + \underbrace{\theta_i + \tau_i} + \underbrace{\phi\theta_i} h_{it} + \varepsilon_{it}$$

$= \alpha_i$, HH Specific Intercept (HH specific average yield)

HH Specific Slope (HH specific gain to hybrid)

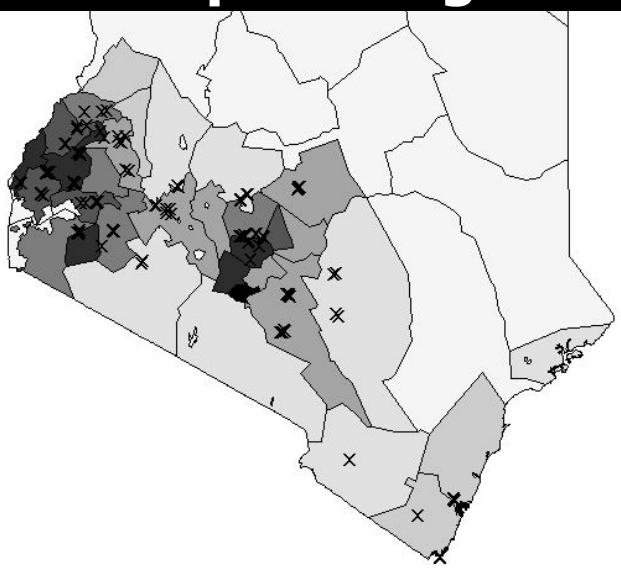
The covariance between the household specific slopes and intercepts:

$$cov(\alpha_i, \varphi\theta_i) = \varphi\sigma_\theta^2$$

Structural coefficient $\boldsymbol{\varphi}$ tells us if high intercept HHs are high slope HHs

What Regressions to Run

Sample Villages



Transitions in Hybrid (Switching)

Fraction of Sample (%)	Transition
20.38	000
2.83	001
6.07	010
5.99	100
4.91	011
3.16	101
7.15	110
49.50	111

What Regressions to Run?

- Regression of output/acre on hybrid use: coefficient of 1.024
- Control for inputs (labor, fertilizer, etc.): coefficient of 0.556
- Control for a household "fixed effect": coefficient of 0.149
- Instrumental variables: coefficient of 1.452
- Many are significantly different from each other, but none analyzes what the return to hybrid is if it differs across farmers

Estimation (Generalize Chamberlain)

The basic yield function for the heterogeneous returns model is:

$$y_{it} = \delta + \theta_i + \beta h_{it} + \phi \theta_i h_{it} + \tau_i + \varepsilon_{it}$$

Project θ_i onto the history and the interactions of the hybrid histories:

$$\theta_i = \lambda_0 + \lambda_1 h_{i1} + \lambda_2 h_{i2} + \lambda_3 h_{i1} h_{i2} + v_i$$

Use Minimum Distance:

- Run a reduced form for each time period (includes **all** hybrid histories) to get **six** reduced form parameters
- These map onto **five** structural parameters ($\varphi\ \beta\ \lambda_1\ \lambda_2\ \lambda_3$)
- The structural parameters are over-identified

What Do I Find?

YES! Dramatic differences in what returns to hybrid would be

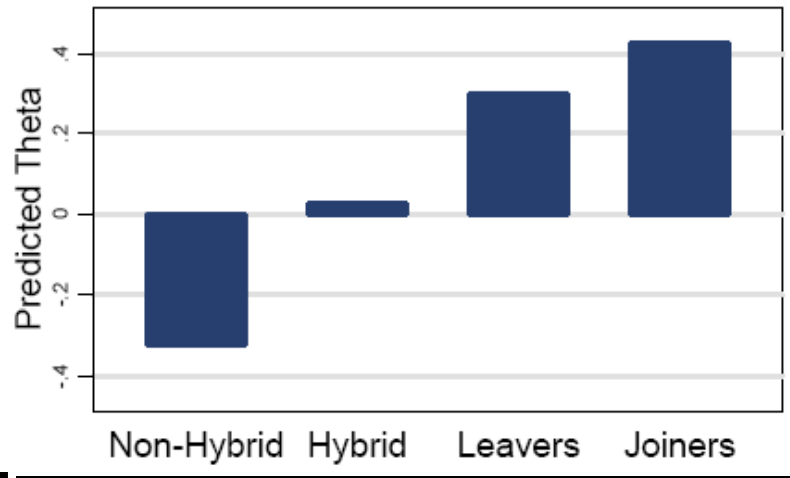
Would those not using the technology have zero returns? NO!

Some of them do! The rest would have even higher than average returns from using hybrid – puzzle deepens!

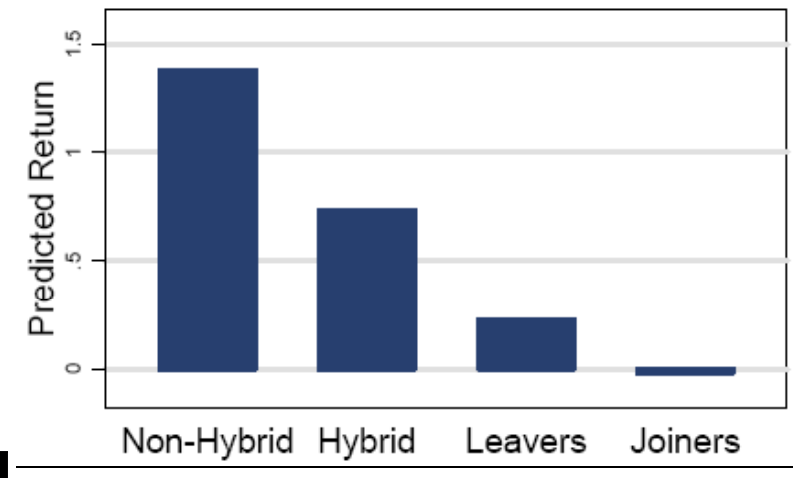
These farmers have high costs that are not reflected in prices (poor access to the technology)

Points to these farmers being pretty "rational"!

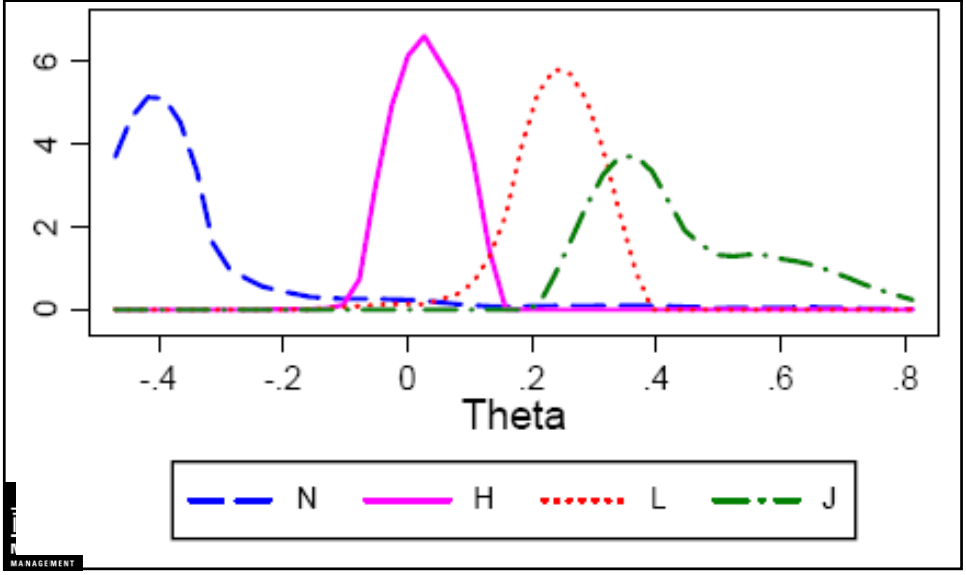
Comparative Advantage I



Implied Returns $(\beta+\varphi\theta_i)$



Comparative Advantage II



What Costs or Constraints?

Dist to Fertilizer (x100)	-0.521 (0.081)	-0.511 (0.081)	-0.521 (0.081)	-0.497 (0.082)
Dist to Motorable Rd (x100)	-0.742 (0.341)	-0.726 (0.342)	-0.741 (0.342)	-0.724 (0.342)
Dist to Tarmac Rd (x100)	-0.259 (0.069)	-0.272 (0.070)	-0.259 (0.069)	-0.293 (0.071)
Dist to Extension (x100)	-0.358 (0.116)	-0.347 (0.117)	-0.358 (0.116)	-0.341 (0.117)
Credit: Tried (x10)	-	0.135 (0.104)	-	-
Credit : Unsuccessful Try (x10)	-	-	0.079 (0.199)	-
Credit: Received (x10)	-	-	-	0.180 (0.109)
P value, Education	(0.000)	(0.000)	(0.000)	(0.000)

Robustness Checks

i. Heckit Selection Equations

ii. ATE, TT, MTE (selection corrected)

iii. IV/LATE Estimates

} Excluded Regressor: Distance to closest fertilizer distributor

LATE/IV Estimates

Exclusion restriction:

Use distance to closest fertilizer seller (km) as the excluded IV

Used for LATE, Heckit and selection corrected ATE, TT and MTE

First Stage: Effect of Distance on Probability of Using Hybrid (x100)	**Second Stage: Effect of Predicted Hybrid on Yields**
-0.525	1.452
(0.097)	(0.419)

Marginal Treatment Effects

Year	Heckman Two-Step Estimates		Implied Treatment Effects		
	λ Hybrid	λ Non-Hybrid	ATE	TT	MTE Slope
1997	-0.833 (0.170)	1.034 (0.724)	2.174	1.138	-1.867 (0.743)
2000	-0.847 (0.118)	-0.615 (0.353)	0.768	0.898	-0.232 (0.372)
2004	-0.890 (0.183)	-0.005 (0.156)	1.331	1.014	-0.885 (0.240)

Conclusion: Policy Questions

We saw the policy implications of the other stories in the literature

Here what are the policy implications? Very different!

You can target policy to be extremely cost effective

If households have zero returns, policy should not encourage adoption of existing varieties via say extension services

Farmers that have low returns and use hybrid are not constrained & would benefit from development of new strains

Role of Infrastructure

Hybrids cause a "reversal of fortune" in that they help those who got the lowest yields from traditional

One way to improve yields (and hence food security), is to develop infrastructure to the areas where hybrid yields are the highest.

Includes encouraging seed and fertilizer suppliers to locate in those areas

Thank you!