

Technology Adoption¹

Pierre Biscaye

January 2025

¹Material from this lecture is drawn from [Jeremy Magruder](#)'s UC Berkeley Microeconomics of Development course and from the Agricultural Technology in Africa [VoxDevLit](#).

Agricultural production in Africa

Explaining low technology adoption

Networks and technology adoption

Centrality and microfinance diffusion: Banerjee et al (2012)

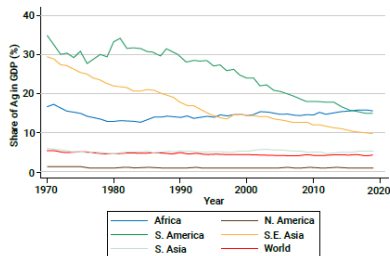
Information thresholds and diffusion: Beaman et al (2021)

Diffusion of pit planting: Beaman et al (2021)

Heterogeneity and hybrid maize adoption in Kenya: Suri (2011)

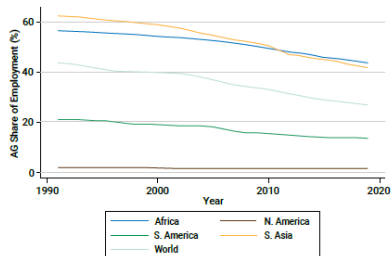
Agriculture shares by global region

Panel A: Share of agricultural GDP across regions of the world, 1970-2019



Source: United Nations, Food and Agriculture Organization (FAOSTAT).

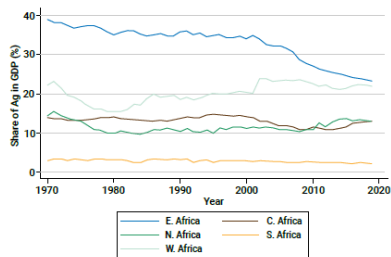
Panel B: Share of agricultural employment across regions of the world, 1991-2019



Source: The World Bank, World Development Indicators (WDI)

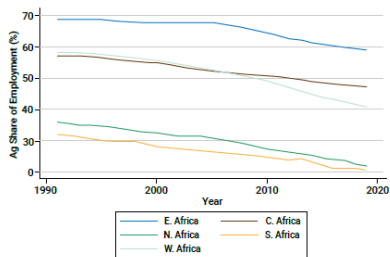
Agriculture shares by African region

Panel C: Share of agricultural GDP across regions in Africa, 1970-2019



Source: United Nations, Food and Agriculture Organization (FAOSTAT)

Panel D: Share of agricultural employment across regions in Africa, 1991-2019

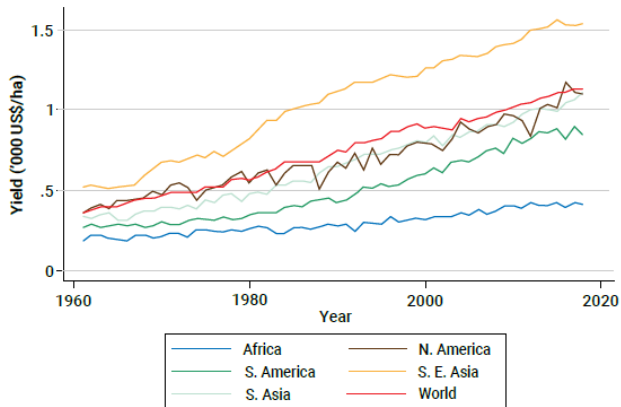


Source: The World Bank, World Development Indicators (WDI)

Structural transformation?

- ▶ Economic development usually involves transition away from agriculture
- ▶ Typical step: shift from small-scale farmers growing for own consumption to large-scale commercial farming
 - ▶ 80% of African farmers have <2 ha
- ▶ Key: improved technology to increase agricultural productivity
 - ▶ Mechanization, agrochemical inputs, improved seeds, etc.
 - ▶ Adoption in Africa well below rest of world
- ▶ Historical technology adoption in Africa: new crops
 - ▶ Maize, cassava, sweet potatoes, cocoa, commercial flowers

Lagging growth in cereal yields

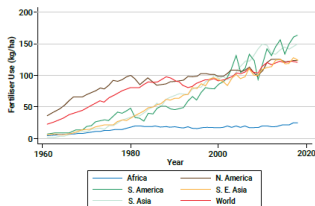


Source: United Nations, Food and Agriculture Organization (FAOSTAT)

Low agricultural technology use

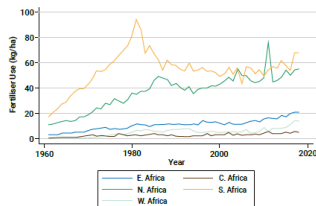
Figure 4: Fertiliser use (Kg/hectare), 1961-2018

Panel A: By region of the world



Source: United Nations, Food and Agriculture Organization (FAOSTAT)

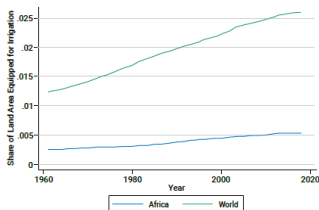
Panel B: Across regions in Africa, 1961-2018



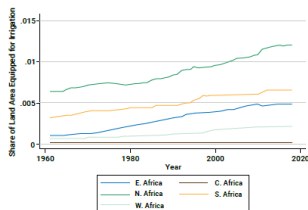
Source: United Nations, Food and Agriculture Organization (FAOSTAT)

Figure 5: Trends in irrigation, 1960-2020

Panel A: Share of land equipped for irrigation in Africa vs. the rest of the world



Panel B: Share of land equipped for irrigation across regions in Africa



Agricultural production in Africa

Explaining low technology adoption

Networks and technology adoption

Centrality and microfinance diffusion: Banerjee et al (2012)

Information thresholds and diffusion: Beaman et al (2021)

Diffusion of pit planting: Beaman et al (2021)

Heterogeneity and hybrid maize adoption in Kenya: Suri (2011)

Why is agricultural technology in Africa stagnant?

- ▶ Much research on this topic
- ▶ Conclusion: no single binding constraint
 - ▶ Different combinations bind for different farmers
- ▶ Implication: need packages of technological, policy, and institutional interventions tailored to different contexts

Why is agricultural technology in Africa stagnant?

- ▶ Much research on this topic
- ▶ Conclusion: no single binding constraint
 - ▶ Different combinations bind for different farmers
- ▶ Implication: need packages of technological, policy, and institutional interventions tailored to different contexts
- ▶ Limited but growing research on this approach
- ▶ Some evidence of positive effects on technology adoption, for example:
 - ▶ Deutschmann et al (2019): group lending, crop insurance, training, input supply, and market facilitation
 - ▶ Bossuroy et al (2022): training, large cash grants, psycho-social interventions

Why is agricultural technology in Africa stagnant?

- ▶ Much research on this topic
- ▶ Conclusion: no single binding constraint
 - ▶ Different combinations bind for different farmers
- ▶ Implication: need packages of technological, policy, and institutional interventions tailored to different contexts
- ▶ Limited but growing research on this approach
- ▶ Some evidence of positive effects on technology adoption, for example:
 - ▶ Deutschmann et al (2019): group lending, crop insurance, training, input supply, and market facilitation
 - ▶ Bossuroy et al (2022): training, large cash grants, psycho-social interventions
- ▶ But also evidence of failures, challenges, and high costs
 - ▶ Integrated Rural Development Programmes in 1970s-1980s (Chambers 2014)
 - ▶ Input intensification programs with costs exceeding benefits from increased yields (Jayne et al 2018)

Credit, liquidity, and savings constraints

- ▶ Agricultural technologies have a cost (of adoption and use) \Rightarrow financial constraints may prevent investment
- ▶ Much research on financial interventions and input adoption in Africa
 - ▶ Generally find significant but small (absolute) increases in adoption
 - ▶ Subsidies can increase adoption, but questions about cost, persistence, and crowding out
 - ▶ \Rightarrow financial constraints not sufficient to explain low adoption, likely not the most binding constraints
- ▶ Low demand for agricultural credit?
 - ▶ Hesitance to list land as collateral, high interest rates, misalignment of repayment schedules and agricultural cycles (de Janvry & Sadoulet 2020)
 - ▶ Rainfall variability \Rightarrow production risk (Abay et al 2022)

Insurance constraints

- ▶ Risk may discourage experimentation and investment
 - ▶ May be particularly relevant for poor farms worried about downside risk (Kala 2017)
- ▶ Lecture 2 discussed role of risk and studies of weather index insurance
 - ▶ Low adoption at market or actuarially fair rates
 - ▶ Roles of high basis risk, loss aversion, present bias
 - ▶ When adopted, has significant but limited and heterogeneous impacts on use of agricultural technologies
- ▶ Other types of risk
 - ▶ Crop price risk (Karlan et al 2011; Arouna et al 2021)
 - ▶ Adoption risk (Adong et al 2020)
- ▶ Challenges in designing low-cost high-quality insurance mechanisms
 - ▶ Remote sensing lowering cost but quality not perfect

Knowledge constraints

- ▶ Lack of information about technologies or their returns
- ▶ Research on how best to provide information and role of learning in social networks
 - ▶ More later: Banerjee et al (2012); Beaman et al (2021)
- ▶ Most studies do not find transformational effects of information on technology adoption (Caldwell et al 2019; Bridle et al 2019)
- ▶ Some general takeaways:
 - ▶ Extension and information most impactful for new technologies or crops
 - ▶ Social networks matter a lot for learning
 - ▶ Beyond acquisition of technical knowledge/information, cognitive and non-cognitive skills may also matter

Limited market access

- ▶ Lack of market access may \uparrow input costs and \downarrow returns from crop sales \Rightarrow low profits from technology adoption
- ▶ High transaction costs for African farmers
 - ▶ High transportation costs, poor supply chain investments, market power among input sellers and output buyers, imperfect information about price and quality, poorly integrated markets
- ▶ Large literature shows market access constraints, growing literature on impacts of that relieving certain constraints
 - ▶ Road improvements (Casaburi et al 2013)
 - ▶ Input fairs (Dillon & Tommaselli 2022; Aggarwal et al 2023)
 - ▶ Mobile phone information interventions (Nakasone et al 2014; Hildebrant et al 2023)
 - ▶ Jan. 2025 J-PAL [Policy Insight](#)

Limited returns to quality

- ▶ Limited markets for output quality: lack of different prices for varying quality of crops in Africa
 - ▶ Some evidence that farmers can upgrade output quality when there are price premiums
 - ▶ But limited premiums for high quality, though some penalties for very low quality
 - ▶ \Rightarrow Little incentive to adopt technologies to upgrade output quality
- ▶ Also challenges in verifying input quality
 - ▶ For example, broad perception that fertilizer is of varying quality when in fact overwhelmingly good (Michelson et al 2021, 2024)
 - ▶ Lack of trust in input quality can \downarrow adoption
- ▶ Why no markets for quality?
 - ▶ Low consumer confidence in ability to assess quality (Prieto et al 2021)
 - ▶ Partly lack of awareness and willingness to pay for third-party verification by African consumers (Hoffmann et al 2020)
 - ▶ Limited introduction of input quality certification schemes (Gilligan et al 2022)

Imperfect input markets

- ▶ **Labor markets:** despite 'slack' in labor, farmers may face difficulties in hiring/providing the right types of labor at the right times \Rightarrow production constraints
- ▶ **Land markets:**
 - ▶ Poorly defined property rights and insecure tenure may decrease investment and prevent land transactions
 - ▶ Land rentals through sharecropping arrangements can dampen productivity (moral hazard), but fixed rent contracts are uncommon (Buchardi et al 2019)
 - ▶ Constraints to land transactions inhibit growth of productive farms, preclude farmers reaching scale needed for mechanization, slow development of value chains
 - ▶ Modest evidence of large-scale land transfers in improving productivity (Deininger & Goyal 2023)

Factors creating heterogeneity in technology adoption

- ▶ Many agricultural technologies are sensitive to local circumstances
 - ▶ Heterogeneity may create challenges for developing and marketing technologies and for farmer learning
 - ▶ Evidence on mismatch between high-income country technologies and low-income country needs (Moscona & Sastry 2022)
 - ▶ In this lecture: Suri (2011)
- ▶ **Soil and land quality:** variation in optimal technology even between plots
- ▶ **Weather:** variability creates heterogeneity in returns, requires long-term perspective
- ▶ **Market access:** creates variation in costs and returns

Potential policy actions

- ▶ Investments in agricultural technology R&D for Africa
- ▶ New technologies that are adaptable or customizable to wider range of circumstances
 - ▶ E.g., customization of seed varieties and extension services
- ▶ Cheaper provision of inputs
 - ▶ Much higher fertilizer prices in Africa than other regions: imports, high transport costs, and low population density
 - ▶ Responses: infrastructure investment, local input production, subsidies, promoting production competition, support for complementary inputs
- ▶ Addressing market failures

Agricultural production in Africa

Explaining low technology adoption

Networks and technology adoption

Centrality and microfinance diffusion: Banerjee et al (2012)

Information thresholds and diffusion: Beaman et al (2021)

Diffusion of pit planting: Beaman et al (2021)

Heterogeneity and hybrid maize adoption in Kenya: Suri (2011)

Networks are a key source of information about new ideas

- ▶ New job opportunities
- ▶ New productive technologies
- ▶ New health products
- ▶ New consumption opportunities
- ▶ Many, many more...
- ▶ Businesses, governments, NGOs market new technologies through networks
 - ▶ Common agricultural model: train seed/lead/innovative farmers, expect them to influence many
 - ▶ Much research showing social learning is important

Information a prerequisite to technology adoption

Adoption game

- ▶ How many of you would adopt a new technology under certain conditions?

What is the role of networks in technology diffusion?

1. Conley & Udry (2010): Diffusion of pineapple planting in Ghana
 - ▶ Demonstrate role of learning from (successful) neighbors about pineapple adoption and input use; no social learning about input choices for known crops
2. Banerjee et al (2012): Diffusion of microfinance in Karnataka
 - ▶ MFI enrolled local “leaders”: shop-keepers, teachers, self-help group leaders to be ambassadors to the program
 - ▶ Microfinance adopters 7x more likely to share information
 - ▶ ‘Diffusion centrality’ of ambassador predicts spread and speed of adoption
3. Beaman et al (2021): Diffusion of pit planting in Malawi
 - ▶ Central “seed” farmers chosen according to a particular diffusion model
 - ▶ Demonstrate importance of understanding diffusion process

Measuring network connections

- ▶ Analysis requires a census mapping network relationships
 - ▶ Expensive and time consuming to collect
 - ▶ Second degree connections really important and poorly approximated by a random sample
- ▶ Banerjee et al (2012): Over 50% of households censused in 43 villages; asked about 13 dimensions of network ties
 - ▶ Friends, relatives, who would borrow from, who would lend to, who prays with, etc.
- ▶ Beaman et al (2021): Over 80% of household censused in 200 villages, focused on agricultural learning networks
 - ▶ Who they talk to about agriculture, early adopters of other technologies, labor-sharing group members, etc.
- ▶ In both cases, assume all connections bilateral (I know you means you know me)

Network characteristics

- ▶ Define A the *Adjacency Matrix*. Element $a_{ij} = 1$ if i is connected to j , 0 otherwise
- ▶ **Degree**: number of connections for a particular node ($\sum_j a_{ij}$)
- ▶ **Eigenvector Centrality**: Weight the number of connections by the importance of those connections

$$\lambda x = Ax \text{ Identify largest eigenvalue}$$

$$x_i = \frac{1}{\lambda} \sum_j a_{ij} x_j \text{ Normalize eigenvector}$$

- ▶ **Diffusion Centrality**: expected number of times that all nodes are exposed by node i
- ▶ **Communication Centrality**: output from the model in Banerjee et al

Agricultural production in Africa

Explaining low technology adoption

Networks and technology adoption

Centrality and microfinance diffusion: Banerjee et al (2012)

Information thresholds and diffusion: Beaman et al (2021)

Diffusion of pit planting: Beaman et al (2021)

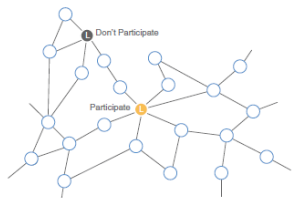
Heterogeneity and hybrid maize adoption in Kenya: Suri (2011)

Microfinance in India

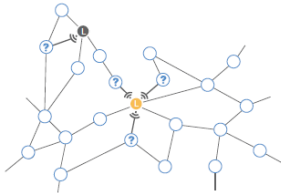


Conceptualizing diffusion

A Leaders are informed and make a decision on participation.



B Information is passed on by leaders; leadership participation affects probability of information sharing.



C Newly informed nodes make a decision on participation.



Fig. 1. Diffusion of information and participation. (A) Informed leaders. (B) Leaders passing information; the participating leader passes at a higher rate. (C) The participation decision of newly informed nodes. (D) Nodes pass information again, which can vary according to participation. (E) Newly informed nodes deciding again to participate.

D All informed nodes pass on information further; the probability of information sharing is, again, based on participation.



E Fresh round of newly informed nodes make participation decision



Two candidate models

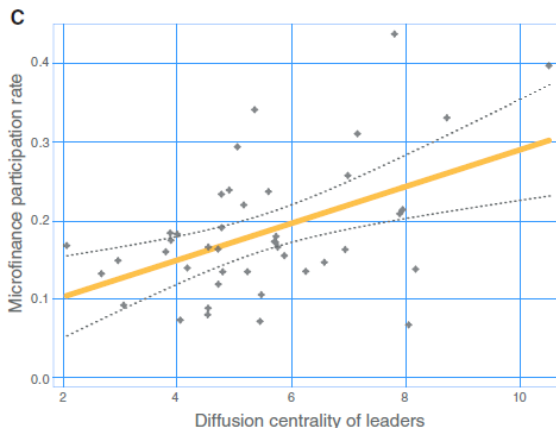
1. Information: $p_i = \Lambda(\alpha^I + \beta^I x_i)$
 - ▶ If you are connected to an adopter, your adoption is only a function of your own characteristics
2. Endorsement: $p_i = \Lambda(\alpha^E + \beta^E x_i + \lambda A_i / N_i)$
 - ▶ Your adoption decision depends on your characteristics and also how many of your connections adopt

First part of Banerjee et al (2012) structurally estimates this model

- ▶ Challenge: don't observe who was informed by a leader but did not adopt (versus not being informed)
- ▶ Simulated methods of moments: choose moments of adoption patterns within the data and find the parameter vector that minimizes the difference between simulated adoption and those estimates

- ▶ Adoption affects decision to share information
- ▶ Not much role of endorsement effect:
 - ▶ People who are connected to adopting leaders are more likely to adopt
 - ▶ People who are connected to non-adopting leaders are also more likely to adopt (though smaller)
 - ▶ Informed people are not more likely to adopt if informed friends adopt
- ▶ Find that centrality of initial 'seeds' (injection leaders) strongly predicts eventual village-level participation

Network characteristics of seeds matter



- ▶ Aligns with a lot of research on diffusion
- ▶ Challenge: network maps are rare
- ▶ Question: tradeoffs between identifying a central seed vs having many seeds (Akbarpour et al 2020)

Outline

Agricultural production in Africa

Explaining low technology adoption

Networks and technology adoption

Centrality and microfinance diffusion: Banerjee et al (2012)

Information thresholds and diffusion: Beaman et al (2021)

Diffusion of pit planting: Beaman et al (2021)

Heterogeneity and hybrid maize adoption in Kenya: Suri (2011)

Modeling diffusion

- ▶ Both studies: do we see *different* diffusion patterns based on initial technology 'seeds'?
- ▶ Choice of seeds influenced by measures of centrality but also model of diffusion
- ▶ Beaman et al (2021): models of diffusion based on epidemiology \Rightarrow 'contagion' of information
 - ▶ Simple contagion: j informed if any connection i is information
 - ▶ Complex contagion: Need to reach a certain threshold λ of connections \Rightarrow enough information to change adoption decision
- ▶ Rationalization: if adoption is difficult or risky, may want to observe multiple data points indicating adoption is effective before deciding
- ▶ Motivates study of diffusion with seed selection determined based on simple contagion or complex contagion with $\lambda = 2$

Seed identity matters in complex contagion

- ▶ Simple contagion: select enough random seeds and should be able to reach a good part of network
 - ▶ Ideally want more distant seeds to reach different parts of network
 - ▶ With 2 seeds: one person in center, and one person on periphery
- ▶ Complex contagion: optimal seed selection more complicated
 - ▶ Adoption requires multiple connections: these are not random
 - ▶ Would require many more random draws to probabilistically generate frequent shared ties
 - ▶ Generates a substantial risk of no diffusion at all if seeds not chosen carefully
 - ▶ \Rightarrow Important to understand full network of relationships

Example network and seed selection

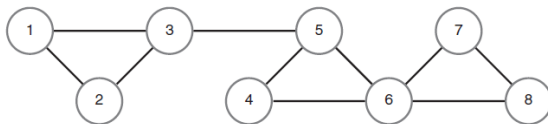


FIGURE 1. AN EXAMPLE NETWORK

What are the 2 optimal seeds under simple contagion? Complex contagion with $\lambda = 2$?

Example network and seed selection

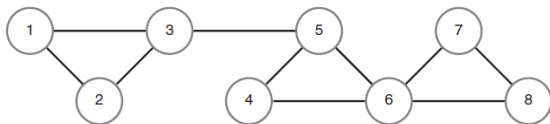


FIGURE 1. AN EXAMPLE NETWORK

What are the 2 optimal seeds under simple contagion? Complex contagion with $\lambda = 2$?

- ▶ Simple: 6 and 1, 2, or 3 \Rightarrow everyone informed in period 1
 - ▶ 70% of random seed pairings lead to full information by period 2
 - ▶ No targeting necessary

Example network and seed selection

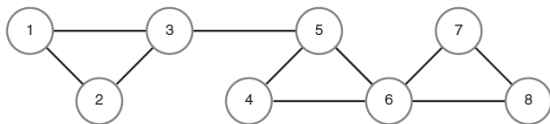


FIGURE 1. AN EXAMPLE NETWORK

What are the 2 optimal seeds under simple contagion? Complex contagion with $\lambda = 2$?

- ▶ Simple: 6 and 1, 2, or 3 \Rightarrow everyone informed in period 1
 - ▶ 70% of random seed pairings lead to full information by period 2
 - ▶ No targeting necessary
- ▶ Complex: more difficult
 - ▶ 4 seed pairings can achieve 50% full information for adoption among non-seeded, not possible to get higher
 - ▶ Example: seed 5 and 8 \Rightarrow 6 informed period 1 \Rightarrow 4 and 7 informed period 2 \Rightarrow ends

Agricultural production in Africa

Explaining low technology adoption

Networks and technology adoption

Centrality and microfinance diffusion: Banerjee et al (2012)

Information thresholds and diffusion: Beaman et al (2021)

Diffusion of pit planting: Beaman et al (2021)

Heterogeneity and hybrid maize adoption in Kenya: Suri (2011)

Planting technologies in Malawi

A. Ridge planting



B. Pit planting

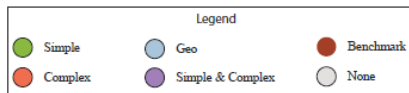
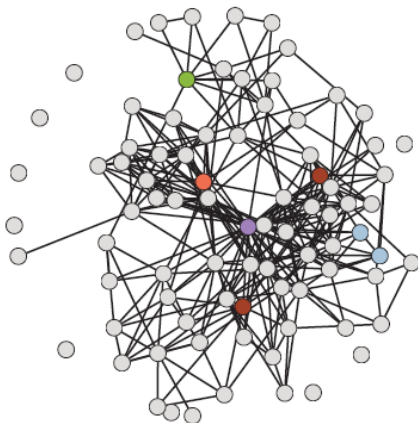


Study setup

- ▶ Collected detailed social network and location data in 200 villages in Malawi
- ▶ Simulated threshold models to obtain optimal 2 seed farmers
- ▶ Random village assignment to 4 treatments:
 1. Optimal partners assuming simple contagion
 2. Optimal partners assuming complex contagion
 3. 'Geography': centrality based on physical location
 4. 'Benchmark': asked government extension agents to pick seeds following usual protocol
 - ▶ No restriction on information they can use
- ▶ Extension agents train assigned seed farmers on pit planting
- ▶ Measure adoption in random sample in all villages

Example village network

Village 42

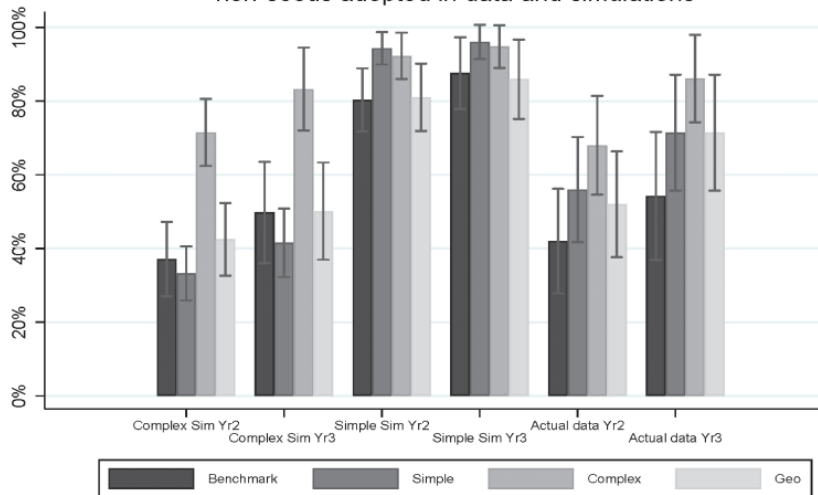


Implementing the experiment

- ▶ Trained seeds were more likely to adopt pit planting than counterfactual seeds (.3 vs .05)
- ▶ Seeds in all treatments equally likely to adopt
- ▶ Yields higher among seeds than counterfactual seeds (about 12%)
- ▶ Seeds talked to other people about pit planting

Seed selection affects probability any non-seed adopts pit planting

Figure 2: % of villages where at least some non-seeds adopted in data and simulations



Summary of adoption results

- ▶ Inducing adoption among untrained is hard, despite apparent high returns
 - ▶ After 3 years, 10% individual-level adoption
 - ▶ 50% of benchmark villages show no evidence of adoption outside trained seeds
- ▶ Optimal seed selection outperforms benchmark
 - ▶ Large extensive margin effects
 - ▶ Small absolute but large relative intensive margin effects
 - ▶ Complex contagion targeting seems most robust, but can't reject similar effects as simple contagion
 - ▶ Limited gains from geographic targeting

How to evaluate whether this looks like complex contagion?

- ▶ Suggest complex contagion is a myopic learning process
- ▶ Suppose there is a small cost to observe signals about a new technology in your network
 - ▶ When is it worthwhile to pay that cost?
 - ▶ Only if you might change your adoption decision based on that signal
- ▶ Tests of complex contagion
 1. Probability of no adoption (above)
 2. Learning problem: treatments should be more effective when the learning experience is more useful
 - ▶ Pit planting only recommended on flat land
 - ▶ Acquiring signal more helpful if it is more novel/unfamiliar
 3. Individual learning patterns

Targeting matters more when the news is good

TABLE 4—HETEROGENEITY IN FARMER-LEVEL ADOPTION DECISIONS ACROSS TREATMENT ARMS

	(1)	(2)	(3)	(4)
Bad Signal \times Complex	0.006 (0.024)	-0.027 (0.036)	0.013 (0.015)	-0.045 (0.033)
Bad Signal \times Simple	-0.008 (0.024)	-0.036 (0.037)	0.019 (0.017)	-0.008 (0.034)
Bad Signal \times Geo	0.002 (0.031)	-0.068 (0.031)	0.031 (0.035)	-0.054 (0.032)
Good Signal	-0.037 (0.017)	-0.062 (0.024)	-0.007 (0.022)	-0.064 (0.038)
Good Signal \times Complex	0.059 (0.018)	0.067 (0.025)	0.054 (0.024)	0.083 (0.030)
Good Signal \times Simple	0.064 (0.021)	0.029 (0.020)	0.054 (0.029)	0.021 (0.020)
Good Signal \times Geo	0.042 (0.020)	0.022 (0.023)	0.026 (0.022)	0.031 (0.029)
Good Signal type	Flat land	Flat land	Unfamiliar tech	Unfamiliar tech
Year	2	3	2	3
Observations	3,546	2,645	3,954	3,023
Mean of Bad Signal in Benchmark treatment (omitted category)	0.066	0.123	0.046	0.104
SD	0.248	0.33	0.21	0.305
<i>p-values for equality in coefficients</i>				
Simple, good = Complex, good	0.828	0.113	0.986	0.032
Complex, good = Geo, good	0.482	0.103	0.297	0.138
Simple, good = Geo, good	0.364	0.755	0.351	0.680

Only multiple connections matter for learning

TABLE 5—DIFFUSION WITHIN THE VILLAGE: KNOWLEDGE

	Heard of pit planting			Knows how to pit planting		
	(1)	(2)	(3)	(4)	(5)	(6)
Connected to 1 seed	0.002 (0.024)	0.030 (0.022)	0.016 (0.029)	0.017 (0.016)	0.021 (0.017)	−0.031 (0.023)
Connected to 2 seeds	0.084 (0.038)	0.124 (0.040)	0.064 (0.064)	0.062 (0.028)	0.068 (0.029)	0.110 (0.051)
Within path length 2 of at least one seed	−0.018 (0.028)	0.016 (0.027)	0.067 (0.042)	0.005 (0.018)	0.022 (0.021)	0.028 (0.028)
Year	1	2	3	1	2	3
Observations	4,155	4,532	3,103	4,155	4,532	3,103
Mean of reference group (no connection to any seed)	0.223	0.286	0.391	0.057	0.095	0.147
SD of reference group	0.416	0.452	0.488	0.232	0.293	0.355
<i>p</i> -value for 2 connections = 1 connection	0.018	0.013	0.442	0.072	0.091	0.004

Conclusions

- ▶ People adopt new technologies more when those technologies are introduced by central people
 - ▶ Consistent with network theory
- ▶ Information diffusion has characteristics of complex contagion
 - ▶ Suggests social learning may need some more modeling
 - ▶ Complex contagion produces rational ignorance: costs of acquiring information
 - ▶ Adopting a new planting system is high-stakes. What about other decisions?
 - ▶ Implications for identification of seeds for diffusion; cost and scalability?

Outline

Agricultural production in Africa

Explaining low technology adoption

Networks and technology adoption

Centrality and microfinance diffusion: Banerjee et al (2012)

Information thresholds and diffusion: Beaman et al (2021)

Diffusion of pit planting: Beaman et al (2021)

Heterogeneity and hybrid maize adoption in Kenya: Suri (2011)

Hybrid maize in Kenya

- ▶ Very large yield advantages of hybrid of traditional maize
 - ▶ Evidence from agronomic trials and farm data
- ▶ Available in Kenya for decades, but adoption constant at around 70% of farmers
 - ▶ Strong spatial component: near universal adoption in some provinces, very low in others
- ▶ What could explain this?
 - ▶ Low access to hybrid maize
 - ▶ Greater risk than traditional maize
 - ▶ Access to credit
 - ▶ Lack of information
 - ▶ Heterogeneity in returns
- ▶ Which ones seem plausible?

Hybrid maize adoption trends by province

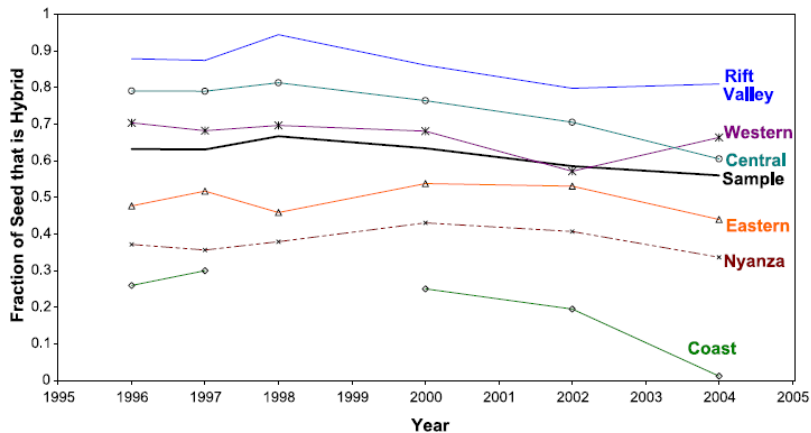


FIGURE 2.—Hybrid maize adoption patterns by province.

Similar patterns for inorganic fertilizer

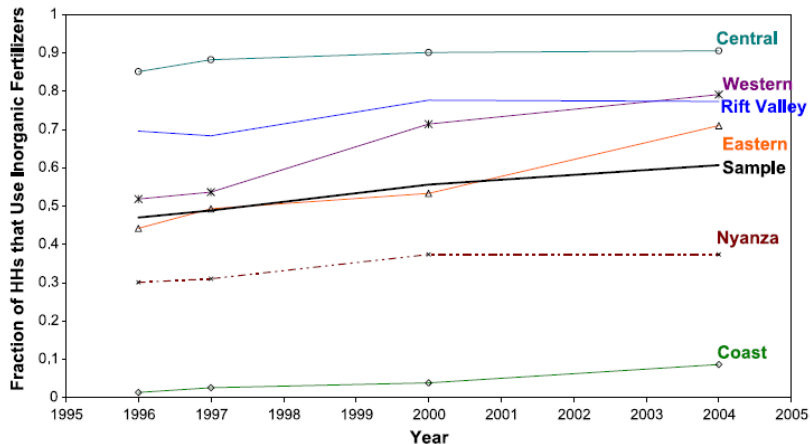


FIGURE 3A.—Fraction of households using inorganic fertilizer by province.

Maize yields by hybrid seed adoption

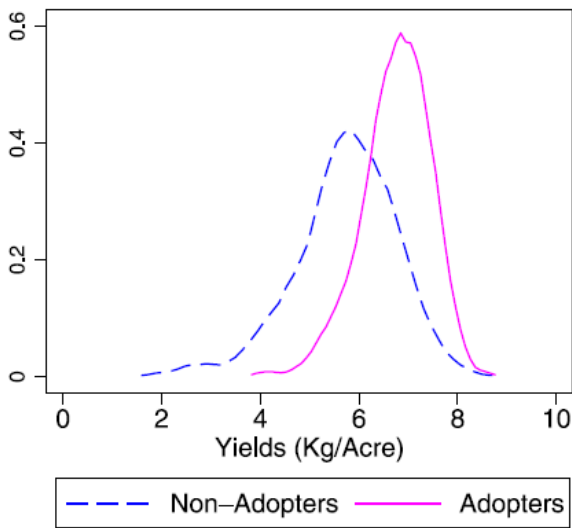


FIGURE 4B.—Marginal distribution of yields by sector, 2004.

Theoretical set-up

- ▶ Farmer decides on seed technology at beginning of growing season
 - ▶ Based on information, expectations about growing conditions, and relative costs and benefits of seeds
 - ▶ Risk-neutral, choose to maximize profits per land area
- ▶ Profit functions for $k \in (H, N)$ are:

$$\pi_{it}^k = p_{it}y_{it}^k - (b_t^k s_{it}^k + a_{it}) - \sum_{j=1}^J w_{jit} X_{jit}^k$$

- ▶ p expected output price of maize
- ▶ y^k maize variety yield given inputs
- ▶ b^k per unit seed cost, quantity s^k
- ▶ a fixed cost of obtaining hybrid seed (access differences)
- ▶ w vector of input prices for inputs X

Farmer decision

$$\pi_{it}^k = p_{it}y_{it}^k - (b_t^k s_{it}^k + a_{it}) - \sum_{j=1}^J w_{jit}X_{jit}^k$$

- ▶ Farmer plants hybrid when $\pi_{it}^{*H} > \pi_{it}^{*N}$
 - ▶ * indicates optimizing input choices for each
- ▶ Simplifications/assumptions based on the data
 - ▶ Optimized inputs quantities other than fertilizer are similar for both hybrid and nonhybrid
 - ▶ Fertilizer only used with hybrid seed, in fixed proportion to land allocation seed use \Rightarrow fertilizer costs enter into b^H
- ▶ Decision then simplifies to planting hybrid if $(y_{it}^{*H} - y_{it}^{*N}) > A_{it} + \Delta_{it}^s$
 - ▶ A_{it} access costs
 - ▶ Δ_{it}^s real differences in input costs (seed and fertilizer)
- ▶ The decision comes down to yield differences (after controlling for cost differences)

Estimation approach

- ▶ Correlated random coefficients model
- ▶ Allows two forms of household-specific heterogeneity in maize production: absolute advantage (across varieties) and comparative advantage in hybrid maize
 - ▶ Novel econometric contribution in estimating role of comparative advantage
- ▶ Panel data on maize-growing Kenyan farmers: 1996-2004
- ▶ Stable aggregate hybrid seed adoption over time, but 30% of households switch in and out across periods
 - ▶ This is important for identifying production advantages

Results: returns to maize yields

- ▶ Strong evidence of heterogeneity in returns to hybrid maize
- ▶ Wide variation in estimated gross returns in different approaches
 - ▶ OLS: 50-100%; FE: 0%; IV: 150-200%
 - ▶ CRC: mean 60%, but wide distribution

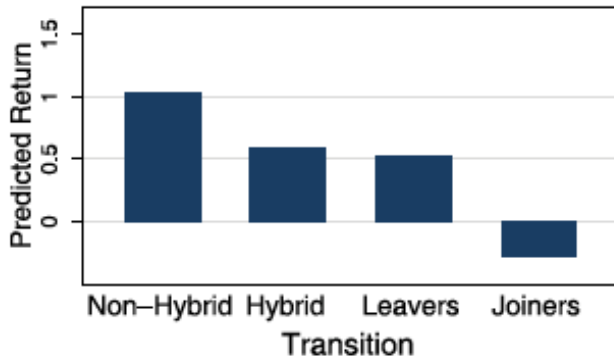


FIGURE 5B.—Distribution of returns.

Explaining adoption decisions

Identifies 3 subgroups of farmers:

1. Small group: 150% estimated *gross* returns to hybrid but choose not to adopt (non-hybrid stayers)
 - ▶ Show this is explained by supply and infrastructure constraints, e.g., distances to seed/fertilizer distributors \Rightarrow low *net* returns
2. Larger group: medium estimated returns, adopt hybrid every period (hybrid stayers)
3. Remainder: estimated returns closer to 0, switch in and out of hybrid based on shocks to cost and access to hybrid seed and fertilizer (leavers and joiners)

Main conclusion: differences in take-up driven by heterogeneity in profitability plus variation in access and costs

Policy implications

- ▶ Low adoption (in this context) is rational
 - ▶ Only surprising because of baseline beliefs about broad productive advantages of hybrid seed, and lower adoption rates in African countries than elsewhere in world
 - ▶ Inappropriate to encourage complete adoption of a technology with high *average* returns among *existing* adopters
 - ▶ Should not treat returns to technology as homogeneous
- ▶ Possible response: more R&D in locally tailored varieties
 - ▶ 20-40 varieties of rice released annually in India since 1970, plus 10-20 varieties of both maize and wheat
 - ▶ In Kenya maize is the staple but < 5 newer varieties introduced per year from 1970-2000, and only more recently reaching India's levels
 - ▶ Bird et al (2022) show locally adapted maize varieties have important yield and revenue effects in Kenya
- ▶ Additional response: reduce input constraints for potential high-productivity farmers if they can be identified