Technology adoption

(and development economics)

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October 11th, 2022

Outline

1. Development economics, evidence-based policy, and rise of RCTs
   - Fundamental problem of causal influence
2. Technology adoption in households
   - Anti-malarial bednets: Free distribution or cost sharing?
3. Technology adoption in firms
   - Soccer balls: Organizational barriers to technology adoption
   - Management

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Recent trend towards evidence-based policy and RCTs in development economics

- Development economics used to be a largely theoretical field, focused on very big questions
  - In the last 20 years it has become more empirical
  - Heavily relient on Randomized Control Trials (RCTs) - experiments testing (often practical) things, c.f. medical trials.
- NGOs and aid used to be evaluated on whether they reached the correct recipients - targeting the poor
  - Corresponding shift in the last 20 years towards evidence-based policy. Is the money spent having an impact? How could its impact be increased?

Who is associated with shift to experimental approach?

The Sveriges Riksbank Prize in Economic Sciences in Memory of Alfred Nobel 2019

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Michael Kremer

"For their experimental approach to alleviating global poverty"

"[Their research] has considerably improved our ability to fight global poverty. In just two decades, their new experiment-based approach has transformed development economics, which is now a flourishing field of research."

Who is associated with shift to experimental approach?

- Others:
  - Many other academics
    - Big NGOs: J-PAL, IPA, Evidence Action, Give Directly, BRAC
  - Aid agencies / multinationals, especially places like USAID DIV, DIME (World Bank)
- Ties in with Effective Altruism movement (e.g. GiveWell)
- One justification: prioritizes collecting data, observing reality. What works is often very different from what may expect
- Another justification: the econometrics are very transparent and easy to explain to policymakers.

Potential outcomes framework

- Consider a binary treatment W: 1 for treated, 0 for control
- Want to know whether W affects an outcome Y (e.g. W is going to university, Y is earnings at 30; or W is using a bednet, Y is anemia).
- Ex-ante, each individual i has two **potential outcomes**, $Y_i(1)$ if treated, $Y_i(0)$ if non-treated
  - So $Y_i = Y_i(1)W_i + Y_i(0)(1 - W_i)$
- The **(causal) treatment effect** for individual i is $Y_i(1) - Y_i(0)$. This is ultimately what we care about

Fundamental problem of causal influence

- **Fundamental problem of causal influence**: ex-post, only one of the two outcomes is realized, $Y_i(1)$ or $Y_i(0)$
  - We will not be able to estimate the treatment effect for any one individual
  - But we can try to estimate statistics concerning the treatment effect for some sample of individuals
- We do observe average outcomes in treated and non-treated groups, $E[Y_i(1)|W_i = 1]$ and $E[Y_i(0)|W_i = 0]$

Estimating average treatment effects

- Consider the difference between treated and control groups:

$$
\begin{aligned}
& E[Y_i(1)|W_i = 1] - E[Y_i(0)|W_i = 0] \\
= \; & E[Y_i(1)|W_i = 1] - E[Y_i(0)|W_i = 1] \\
& + E[Y_i(0)|W_i = 1] - E[Y_i(0)|W_i = 0] \\
= \; & \underbrace{E[Y_i(1) - Y_i(0)|W_i = 1]}_{\text{Average treatment effect on the treated (ATT)}} \\
& + \underbrace{E[Y_i(0)|W_i = 1] - E[Y_i(0)|W_i = 0]}_{\text{Selection effect (bias)}}
\end{aligned}
$$

- **Selection effect (bias)**: difference in the underlying characteristics of the treated and non-treated populations which leads to a difference in their potential outcomes
- Often we have an intuition for the sign of this bias
  - E.g. If $W = 1$ if go to college, Y =wage at 30, what sign do you think the selection effect would have? How about for bednets?

Random assignment solves the selection problem

- Random assignment ensures that potential outcomes are orthogonal to treatment:

$$E[Y_i(0)|W_i = 1] = E[Y_i(0)|W_i = 0]$$

- So $E[Y_i(1)|W_i = 1] - E[Y_i(0)|W_i = 0]$ is an unbiased estimate of the average treatment effect
- When we don't have random assignment, we need to think carefully about the assignment mechanism (W) and restrictions which could make it "as good as random"

Critiques of the RCT approach

Critiques of the RCT approach

- Expensive, certainly not the only way to solve the selection problem
- Identify effect in one setting. Internal vs. external validity
- Only certain policies amenable to RCTs
- Considerations for scale-up (the focus of Y-RISE, a center at Yale)
  - Differences in implementation when done at scale
  - General equilibrium effects

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Why might technology adoption be slow?

- Suppose adaption of a high return technology is low (e.g. fertilizer, or bednets, or vaccines). Possible explanations?

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- Suppose adaption of a high return technology is low (e.g. fertilizer, or bednets, or vaccines). Possible explanations?
  1. Is it really high return?
     - Unanticipated costs / preferences related to use
     - Is the quality available to people high?
     - Private return vs social return
  2. Constraints:
     - Information. Including how to use it
     - Credit constraints. Present bias.
     - Uninsured risk

Policies to boost adoption of technologies?

- What are some potential policies to boost adoption?

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- What are some potential policies to boost adoption?
  1. Information campaigns.
     - How to target? Networks / target "gossips".
     - Principal-agent problems in extension services. Cell phones
  2. Subsidies. Temporary? Who to target (marginal vs infra marginal)?
  3. Insurance
- Let's dig deeper into subsidies for one type of technology, preventative healthcare

Should we subsidize preventive healthcare? The Demand Problem

- Low utilization of cheap life-saving health interventions
- Natural policy question: should we subsidize preventive healthcare?
- Some key elements to consider?

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- Low utilization of cheap life-saving health interventions
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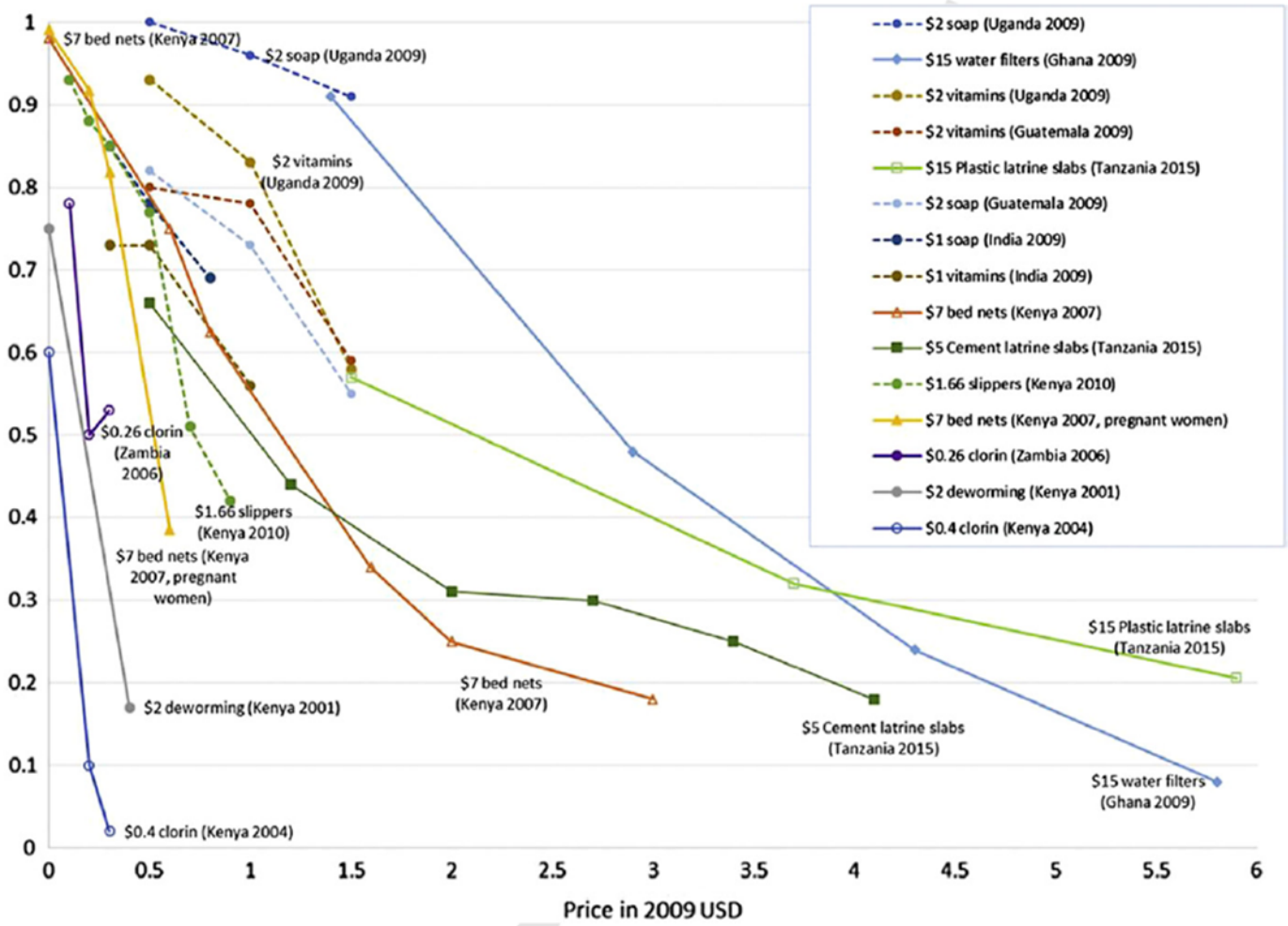
- Some key elements to consider?
  1. (Social) net benefit of treatment (& size of externality)
  2. Is demand elastic?
  3. Selection: How does price affects who gets healthcare? Those who benefit more or less from it?
  4. Usage: How does price affect whether the healthcare product is used?

The elasticity of demand for preventive healthcare



The policy implications

- Other studies finds that small rewards greatly encourage use, e.g. immunization
- Should we make (preventative) healthcare free/even cheaper than free?
- Critics of free healthcare give four arguments against:
  1. Free healthcare results in those who don't need it getting treated
  2. People misuse goods they get for free
  3. People get used to handouts
  4. Others will be discouraged from buying the goods
- For anti-malarial bednets, Cohen and Dupas (2010) refutes the first two arguments, and Dupas' later work refutes the second two (in fact there are important learning effects)

Anti-malarial bednets - Cohen and Dupas 2010

The elasticity of usage of healthcare

- Simple model of optimal subsidies with externalities and inefficient usage
  - Price to household of a net is marginal cost C minus subsidy T
  - H is av. number of nets used appropriately per household
  - N is av. number of nets used inappropriately per household
  - k is size of externality per appropriately used net
- Marginal cost of increasing subsidy T is: $T * \frac{d(H+N)}{dT}$
- Marginal benefit of increasing subsidy T is $k * \frac{dH}{dT}$
- What does the efficient subsidy T^* satisfy?

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- Marginal benefit of increasing subsidy T is $k * \frac{dH}{dT}$
- What does the efficient subsidy T^* satisfy?
  - $T = (k * \frac{dH}{dT})/(\frac{d(H+N)}{dT})$
  - Intuition?

Derivation

- Household i uses h bednets appropriately, utility $u(h)$, and n inappropriately, utility $v(n)$. Fund the subsidy through a lump sum tax T, per average bednet. Utility:

$$U_i = u(h) + v(n) - (C - T)(h + n) + kH - T(H + N)$$

- Households FOC: $u'(h) = v'(n) = C - T$
- Social planner's problem:

$$\text{Max} \quad \Sigma_i U_i = \Sigma_i u(h) + v(n) - C(h + n) + kH$$

(other terms cancelled in aggregate, since $\Sigma_i h = \Sigma_i H$, $\Sigma_i n = \Sigma_i N$)

- FOC social planner's problem (using household FOC)

$$\begin{aligned} \Sigma_i u'(h)\frac{dh}{dT} + v'(n)\frac{dn}{dT} - C(\frac{dh}{dT} + \frac{dn}{dT}) + k\frac{dH}{dT} &= 0 \\ \Rightarrow -T(\frac{dH}{dT} + \frac{dN}{dT}) + k\frac{dH}{dT} &= 0 \end{aligned}$$

Why might price affect usage?

- Three possible effects of positive prices on the likelihood that people who acquire the product use it appropriately:

Why might price affect usage?

- Three possible effects of positive prices on the likelihood that people who acquire the product use it appropriately:
  1. Selection effect:
     - People with high valuation of using the product are exactly those people who are willing to buy it when prices are high
     - Lowering the price means that people who don't really value it are getting the product $\Rightarrow$ lower usage
  2. Sunk cost fallacy (psychological):
     - People get disutility when they don't use an object for which they paid a high price
  3. Signal:
     - Charging a higher price may encourage usage if prices are interpreted as a signal of quality

Potential benefit and ability to pay may not be equal

- But notice that credit constraints can drive the selection effect in the other direction
  - Demand doesn't just depend on willingess to pay - ability to pay matters too.
  - Willingness To Pay and ability to pay may be negatively correlated. Why?

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  - Willingness To Pay and ability to pay may be negatively correlated. Why?
    - e.g. poorly insulated houses have biggest mosquito problem, high need for bednets, but residents likely are poorest people

Basic design

- Randomize price at which prenatal clinics could sell ITNs, from free to 40Ksh ($0.60)
  - Randomization is done at the clinic level. [Aside: implication for standard errors?]
  - Even highest price is a 90% subsidy
- Record sales of ITNs at the clinic and contact details of buyers
- Later visit households of women who bought bednets to check on usage

Results: elasticities of demand and usage

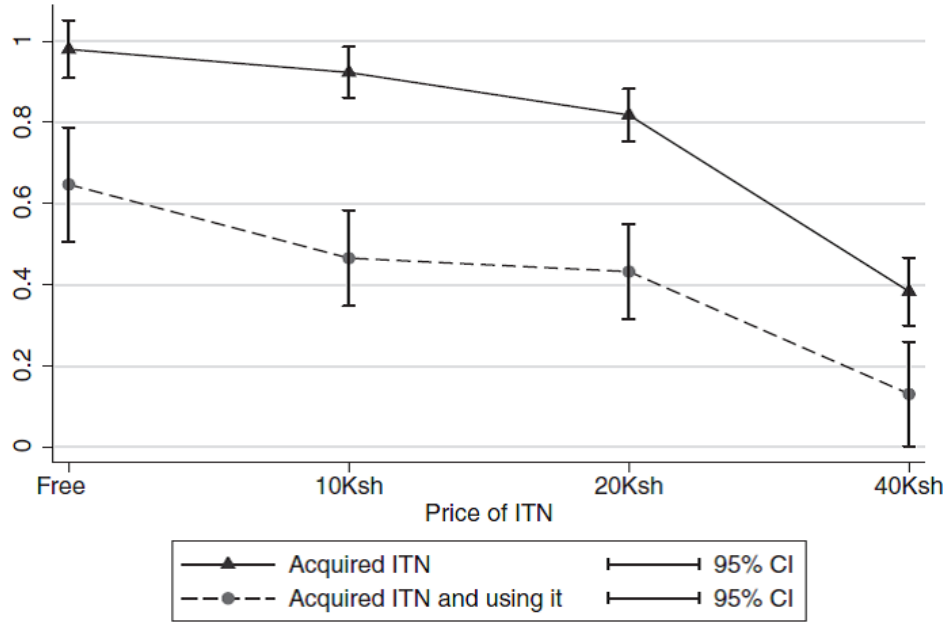

FIGURE I
Ownership vs. Effective Coverage

Sample includes women sampled for baseline survey during clinic visit, and who either did not acquire an ITN or acquired one and were later randomly sampled for the home follow-up. Usage of program ITN is zero for those who did not acquire a program ITN. Error bars represent ±2.14 standard errors (5% confidence interval with fourteen degrees of freedom). At the time this study was conducted, ITNs in Kenya were social-marketed through prenatal clinics at a price of 50 Ksh.

- Demand very sensitive to price
- No evidence that usage is affected by price. Where?
- In the paper they show results unconditionally and conditional on usage. Why?

Sunk cost effect?

- Variation in usage with price could represent selection or a sunk cost effect. Do we care about separating them?

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- Variation in usage with price could represent selection or a sunk cost effect. Do we care about separating them?
  - Different policy implications - e.g. if selection, policies to improve screening
- How can you separate them?
- Randomly reduce the price the woman has to pay, once know they would have bought it anyway

Sunk cost effect?

TABLE VII

SUNK COST EFFECTS? ITN USAGE RATES ACROSS PRICES (CONDITIONAL ON OWNERSHIP), HOLDING WILLINGNESS TO PAY CONSTANT

	Respondent is currently using the ITN acquired through the program					ITN is visibly hanging
	(1)	(2)	(3)	(4)	(5)	(6)
Transaction price	−0.003	−0.006				
	(0.006)	(0.006)				
Transaction price > 0			−0.017	−0.072	−0.065	−0.084
			(0.100)	(0.101)	(0.100)	(0.099)
Got a free ITN the previous year		−0.192			−0.191	−0.165
		(0.100)*			(0.101)*	(0.102)
Still pregnant at time of follow-up		−0.234		−0.195	−0.231	−0.213
		(0.121)*		(0.122)	(0.122)*	(0.125)*
First prenatal visit		0.202		0.199	0.202	0.121
		(0.102)**		(0.103)*	(0.104)*	(0.107)
First pregnancy		0.148		0.184	0.153	0.063
		(0.104)		(0.100)*	(0.104)	(0.106)
Time to clinic		0.000		0.000	0.000	0.000
		(0.001)		(0.001)	(0.001)	(0.001)
Time elapsed since ITN purchase		0.015		0.014	0.015	0.011
		(0.006)***		(0.006)**	(0.006)***	(0.005)**
Observations	132	123	132	124	123	121
Sample mean of dep. var.	0.58	0.58	0.58	0.58	0.58	0.53
F stat		3.23		2.99	3.60	1.97
Prob > F		.00		.01	.00	.07

Notes: Standard errors in parentheses. Estimates are from linear probability models with clinic fixed effects, estimated on the sample of women who (1) visited a clinic where ITNs were sold at a positive price; (2) decided to buy an ITN at the posted price; and (3) were sampled to participate in the *ex post* lottery determining the transaction price they eventually had to pay to take the net home. The transaction prices ranged from 0 (free) to the posted price. Some of the individual control variables are missing for some respondents.

***, **, * Significance at 1%, 5%, and 10% levels, respectively.

- Regressions include clinic fixed effects, and hence control for price / hold willingness to pay constant

Selection by need

- Measured hemoglobin at time of visit to PN clinic

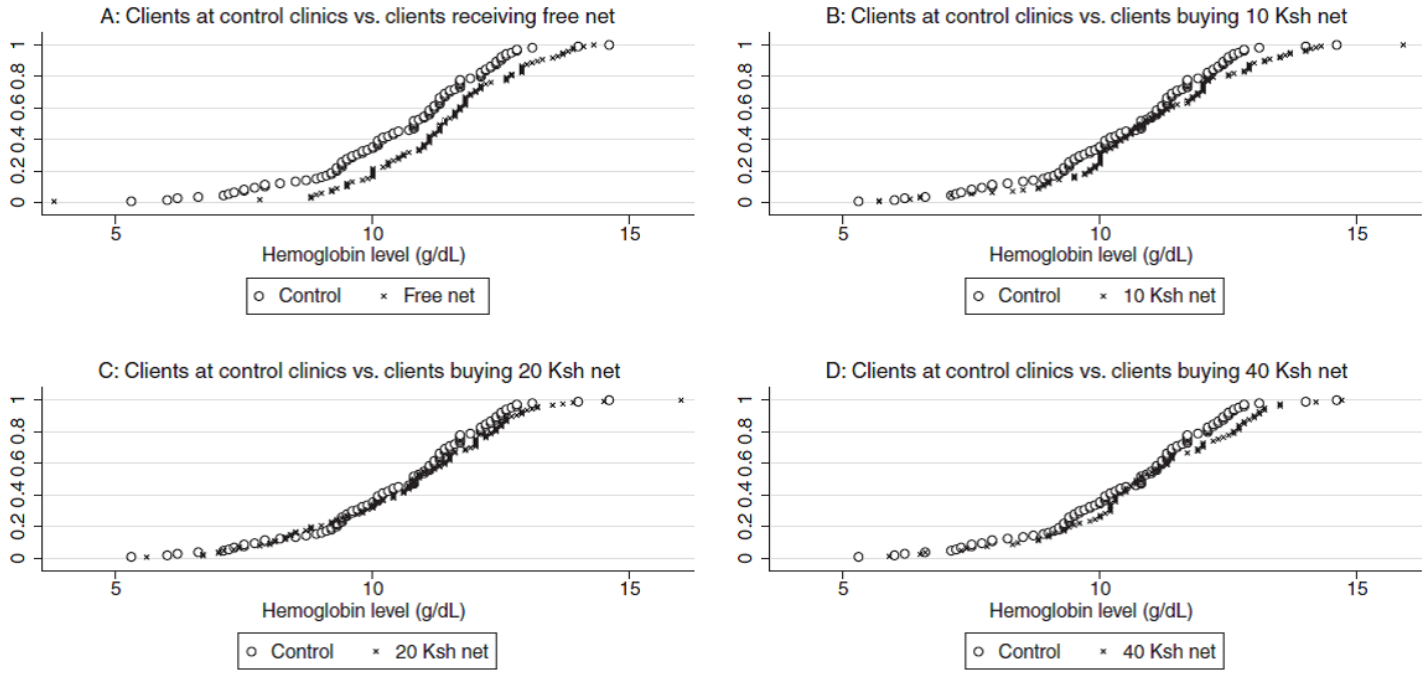

FIGURE III
Cumulative Density of Hemoglobin Levels among ITN Recipients/Buyers

The p-values for Kolmogorov–Smirnov tests of equality of distribution (adjusted for clustering at the clinic level by bootstrap) are .091 (Panel A), .385 (Panel B), .793 (Panel C), and .781 (Panel D). Number of observations: 198 (Panel A), 217 (Panel B), 208 (Panel C), and 139 (Panel D).

- No selection at higher prices (although selection at free price - argue free ITN induced women to come earlier to clinic, when health was better)

Cost-Effectiveness Analysis

- Don't have good data on how externalities vary with the number of people using bednets
  - Consider a range of parameterizations for that function

TABLE IX
COST-EFFECTIVENESS COMPARISONS

		Hypothesis on externality threshold:								
		Low			Medium			High		
		Hypothesis on physical barrier effectiveness:			Hypothesis on physical barrier effectiveness:			Hypothesis on physical barrier effectiveness:		
Subsidy level (%)	ITN price (Ksh)	High (1)	Medium (2)	Low (3)	High (4)	Medium (5)	Low (6)	High (7)	Medium (8)	Low (9)
		Panel A. Child lives saved per 1,000 prenatal clients								
100.0	0	38	37	36	30	27	24	22	17	11
97.5	10	29	28	26	20	16	13	15	11	7
95.0	20	32	30	28	22	19	15	17	12	8
90.0	40	16	14	12	11	8	6	9	7	4
		Panel B. Cost per child life saved (US$)								
100.0	0	200	206	212	255	284	321	352	460	662
97.5	10	234	251	270	348	421	531	448	609	949
95.0	20	189	200	213	274	325	399	361	487	748
90.0	40	175	201	235	261	339	483	302	418	678

Notes: Each cell corresponds to a separate state of the world. To this date, existing medical evidence on the relative importance of the physical barrier provided by an ITN and on the externality threshold is insufficient to know which cells are closest to the actual state of the world. See Online Appendix for details on how these estimates were computed and the hypotheses they rely on.

Big picture: ITNs have successfully reduced Malaria rates

- Bednet distribution has increased
- And malaria infection rates have fallen steeply
- Medical literature arguing a strong causal effect
- https://www.givingwhatwecan.org/post/2015/12/bednets-have-prevented-450-million-cases-of-malaria/#fn7

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Technology adoption in firms: motivation

- Diffusion of new technologies is often (not always) quite slow.
  - Classic studies in agriculture, medicine (Griliches, 1957; Coleman and Menzel, 1966)
  - But also true for larger manufacturing firms (Manseld, 1961: 12 major industrial technologies)
  - Rosenberg (1972): "If one examines the history of the diffusion of many inventions, one cannot help being struck by ... its apparent overall slowness on the one hand and the wide variations in the rates of acceptance of different inventions on the other."

Question: why?

- Hard question to study empirically, especially in manufacturing

Question: why?

- Hard question to study empirically, especially in manufacturing
  - Rare to have information on firms' technology use
  - Even rarer to have:
    - direct measures of costs, benefits of adoption
    - information on what firms know about technology
    - exogenous variation in exposure
- We will see two empirical examples of seemingly profitable technologies which are not adopted, and reasons why

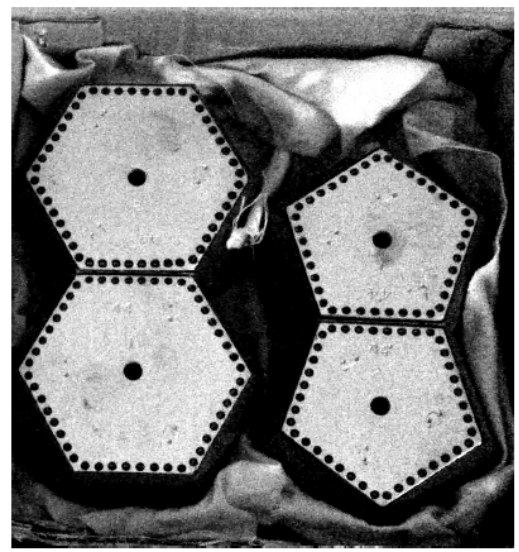
"Organization barriers to technology adoption", Atkin et al. 2017

- Setting:
  - Soccer-ball producers in Sialkot, Pakistan
    - 70% of world hand-stitched production, 40% of total production. 30 million balls/year (WSJ, 2010)
- Two main advantages of setting:
  - 1. Large number of firms (135) producing standardized product using same, simple production process
  - 2. Researchers discovered a useful innovation: a new way of cutting pentagons
    - Allows them (a) to generate experimental variation in access to/knowledge about new technology and (b) to observe adoption very accurately

Existing (cutting) technology

Standard "buckyball" design: 20 hexagons, 12 pentagons.

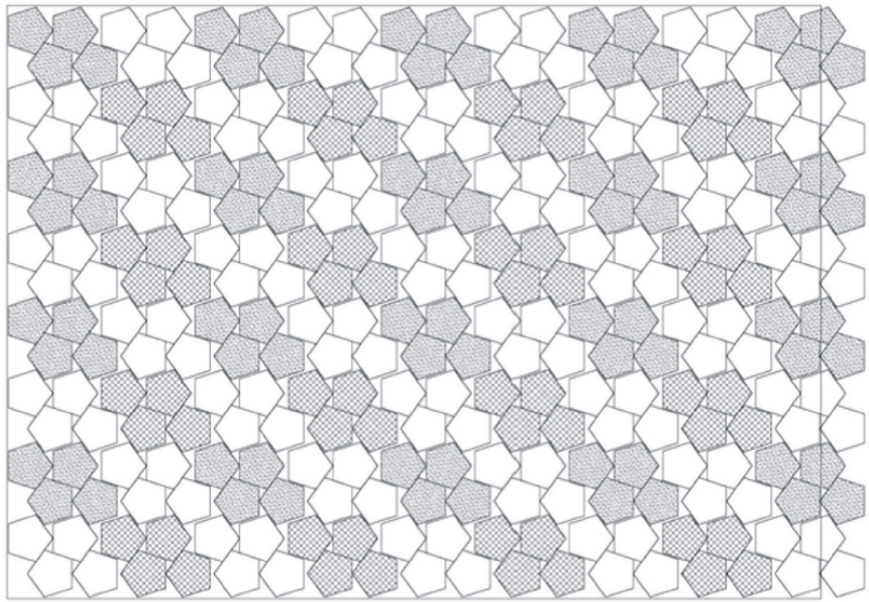
For standard ball, almost all firms use 2-hexagon and 2-pentagon "flush" dies.



Hexagones tessellate, but

Pentagons don't. $\sim$ 20-24% of rexine wasted.

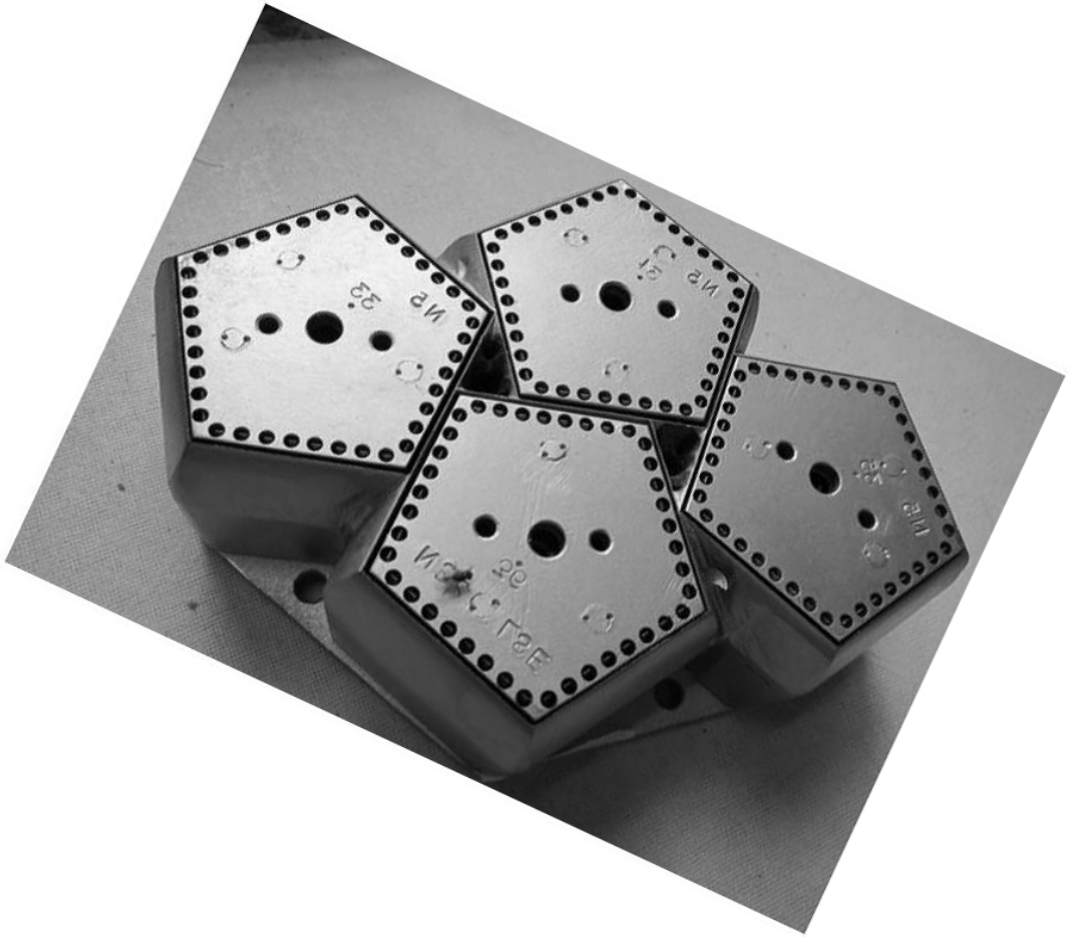
Researchers developed a new pentagon die to reduce wastage



- 44mm-edge pentagons: ∼250 with old die vs. 272 with ours.
- 43.5mm-edge pentagons: ∼258 vs. 280.

New die reduces costs by 1%

- Small saving, but small margins... Represents 10% of profits



- Fixed cost of adoption estimated as $200 per cutter
- Would typically be recovered in 20 days of use

First experiment: tech drop (132 firms into 3 groups)

1. Tech drop:
   - Die + blueprint.
   - 30 min. demonstration, including comparison to existing die.
2. Cash drop:
   - 30,000 Rs cash (US$300) - the amount a die costs
3. "No drop"
   - No intervention

   Dropped technology in May-June 2012, then surveyed approx. every 3 months

Early Finding: Puzzlingly Low Adoption

	Tech Drop	Cash Drop	No Drop	Total
Full sample				
# ever active firms	35	18	79	132
# ever responded	35	17	64	116
# currently active and ever responded	32	15	59	106
# traded in	19	0	0	19
# ordered offset die (beyond trade-in)	1	0	6	7
# received offset die (beyond trade-in)	1	0	4	5
# ever used offset die (>1000 balls, conservative)	4	0	1	5
# ever used offset die (>1000 balls, liberal)	5	0	1	6

- This marks the starting point for this paper
- Objective: investigate why adoption has been so limited among tech-drop firms.

Possible reasons for non-adoption?

Possible reasons for non-adoption?

- Firms don't know about new technology.
  - Cannot explain lack of adoption among tech-drop firms.
- Technology does not in fact reduce variable costs.
  - Cost calculations and revealed preference of Firm Z and other adopters argues against this.
- Profitable to incur fixed costs only for large firms.
  - Cost/benefit breakdown suggests adoption is profitable for large majority of firms (under reasonable discount rates).
  - Within tech-drop group, scale not signicantly associated with adoption (although numbers are small).
- No significant association of adoption with product quality, managerial education/experience, or cutter experience, tenure or IQ.
  - Given small sample size and number of adopters, perhaps not surprising to find no significance. But the puzzle remains.

Hypothesis: Conflict of Interest within Firm

- Main reason cited by firms for non-adoption: employee resistance.

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- Main reason cited by firms for non-adoption: employee resistance.
- Hypothesize that a key problem is misalignment of incentives:
  - Cost savings accrue to owner.
  - Most employees paid piece-rate and new technology slows them down, at least initially.
  - In absence of changes to labor contract, effective wage falls.
  - Employees seek to block adoption, including by misinforming owner about value of technology.
- Formalize this intuition in a simple principal-agent model with strategic communication.

Second Experiment: Incentive Payment

- Randomly assign still-active tech-drop firms to:
  - A. Incentive group:
    - Explain misaligned incentives to owner.
    - Offer incentive payment to one cutter, one printer (US$150 or US$120, roughly monthly income) if they can demonstrate competence using new technology.
    - Pay 1/3 up front, 2/3 conditional on satisfactory performance in 4-6 weeks.
    - 20 rexine sheets to practice with. US$50 to owner to defray overhead costs (electricity, additional practice rexine).
  - B. No-incentive group

Adoption results

	First Stage (1)	OLS (2)	Reduced Form (ITT) (3)	IV (TOT) (4)
Panel A: Short-Run (within 6 months)				
received treatment		0.48***		0.48***
		(0.15)		(0.15)
assigned to group A	0.68***		0.32**	
	(0.12)		(0.12)	
stratum dummies	Y	Y	Y	Y
mean of group B (control group)		0.19	0.19	0.19
R-squared	0.57	0.69	0.60	0.69
N	31	31	31	31
Panel B: Medium-Run (within 1 year)				
received treatment		0.41**		0.37**
		(0.16)		(0.17)
assigned to group A	0.72***		0.27*	
	(0.12)		(0.14)	
stratum dummies	Y	Y	Y	Y
mean of group B (control group)		0.27	0.27	0.27
R-squared	0.60	0.61	0.52	0.61
N	29	29	29	29

- Incentive treatment led to substantially more adoption

Summary

- Results suggest that piece-rate-induced worker resistance is an important barrier to adoption.
  - A relatively small intervention in monetary terms has had a reasonably large impact on adoption.
  - Consistent with explanation that workers were misinforming owners, and that intervention induced truthful revelation.
  - Workers need to expect to share in gains to adoption in order for adoption to be successful.
- Puzzle: why didn't firms just adjust labor contracts?

Summary

- Theory, qualitative evidence suggest two explanations:
  - Changing payment scheme is costly.
  - Owners didn't happen to think of organizational innovation, or did not understand the need for them.
- Complementarities between technological innovations (e.g. offset die) and organizational innovations (e.g. conditional contracts).
- See VoxDev video

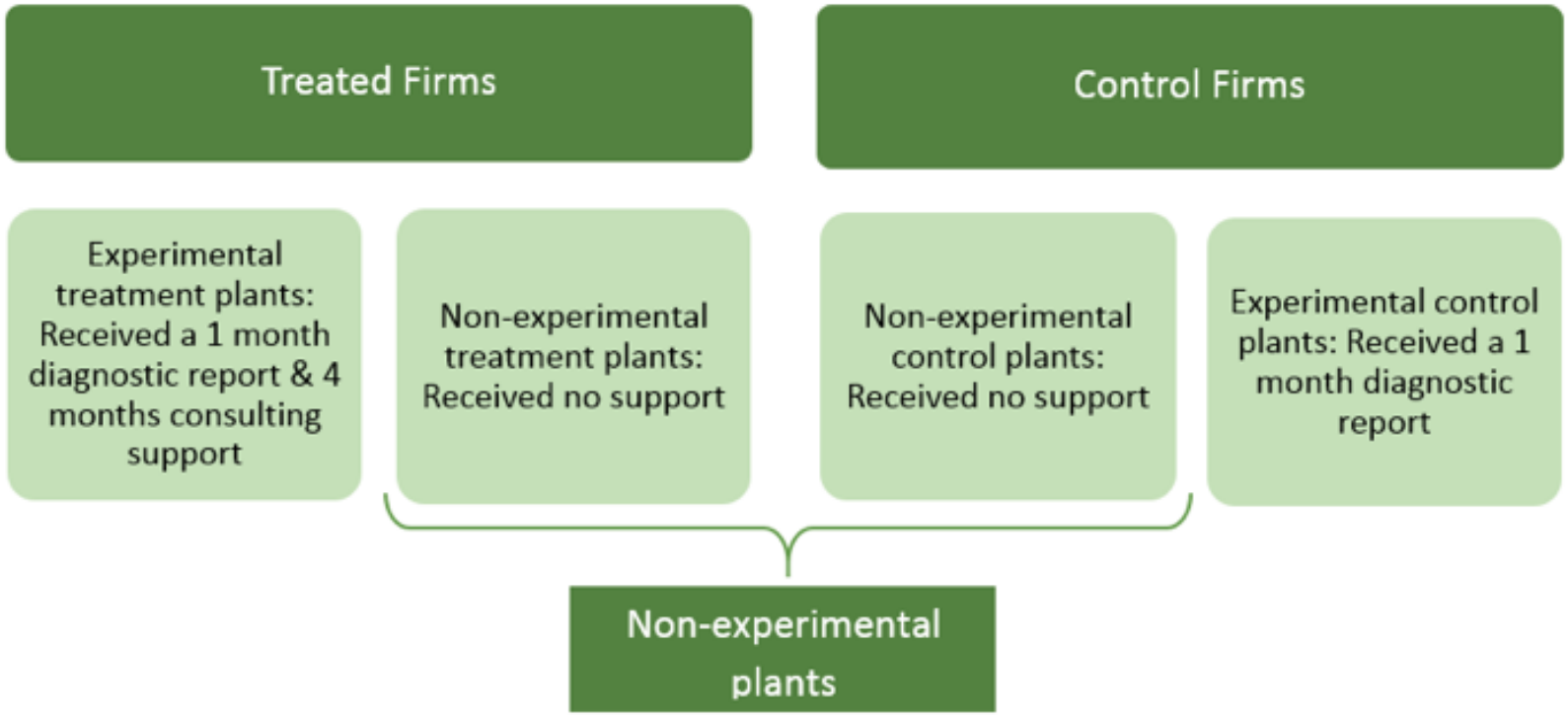
Does Management Matter? Bloom et al. 2011

- Causality?

Experiment on large firms to evaluate the impact of modern management practices

- Experiment on 20 plants in large multi-plant firms (average 300 employees and $7m sales) near Mumbai making cotton fabric
- Randomized treatment plants get 5 months of management consulting intervention, controls get 1 month
- Consulting is on 38 specific practices tied to factory operations, quality and inventory control
- Collect weekly data on all plants from 2008 to 2010.

Experimental design



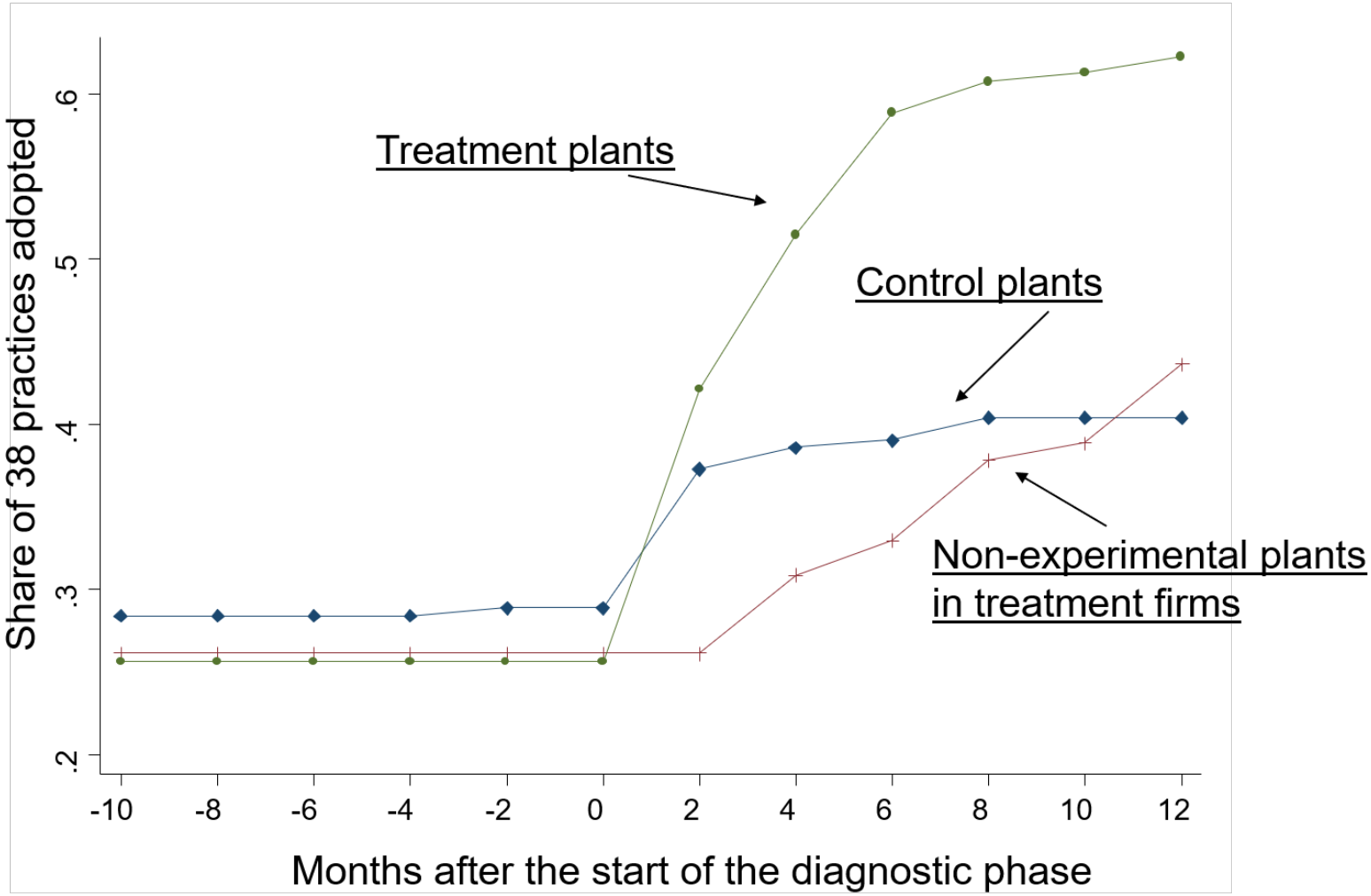
Note firms may have multiple plants. Treatment is at plant level

Plants operate day and night making cotton fabric

Intervention aimed to improve 38 core textile management practices in 5 areas

- Targeted practices in 5 areas: operations, quality, inventory, HR and sales & orders
- Poor inventory storage and quality control were big problems

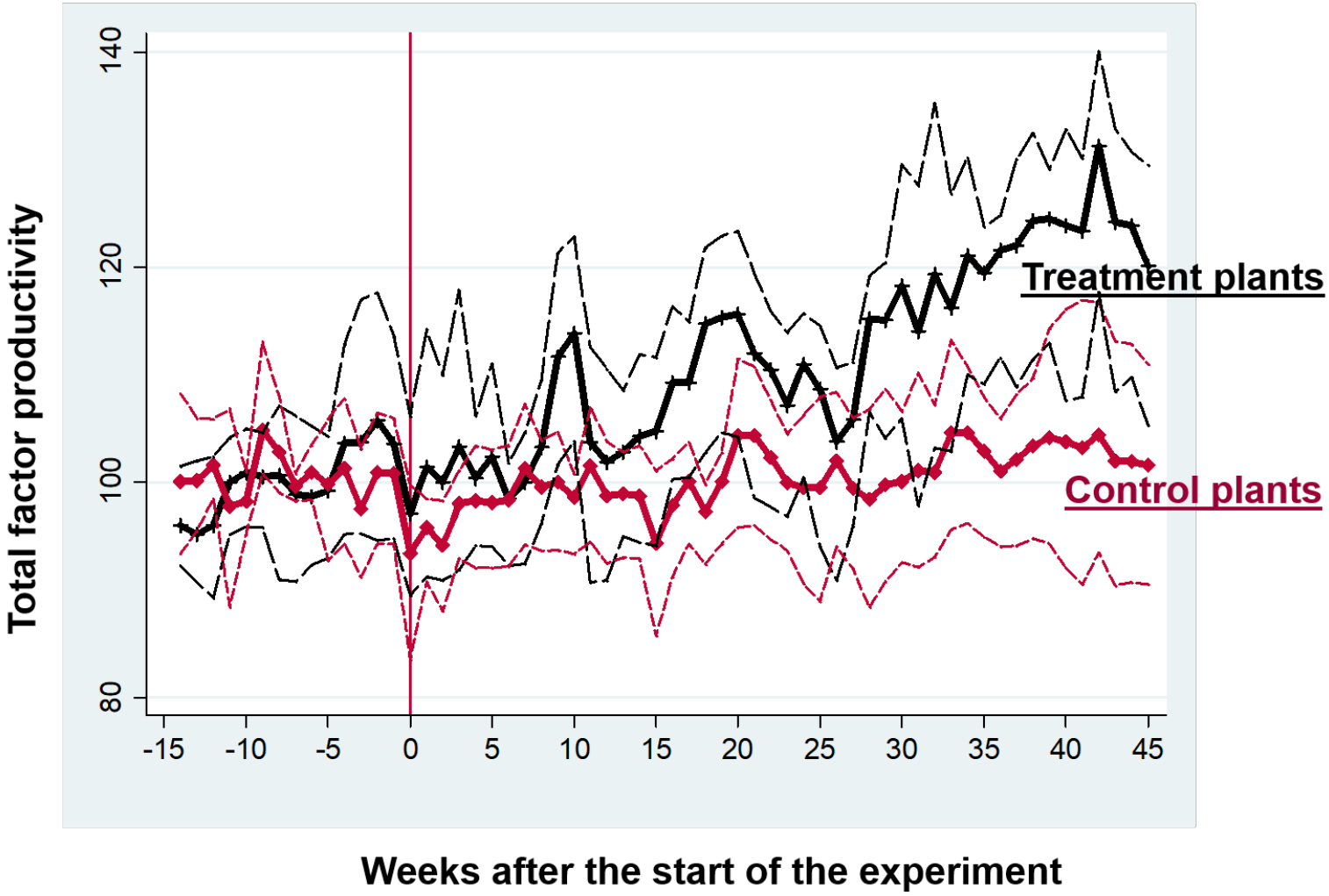
Adoption of the 38 management practices over time



Four outcomes they have weekly data for:

- Quality: Measured by Quality Defects Index (QDI) (higher=worse quality)
- Inventory
- Output
- Productivity

Results: TFP rose in treatment plants vs controls



Note: solid lines are point estimates, dashed lines are 95% confidence intervals

Results: OLS and IV

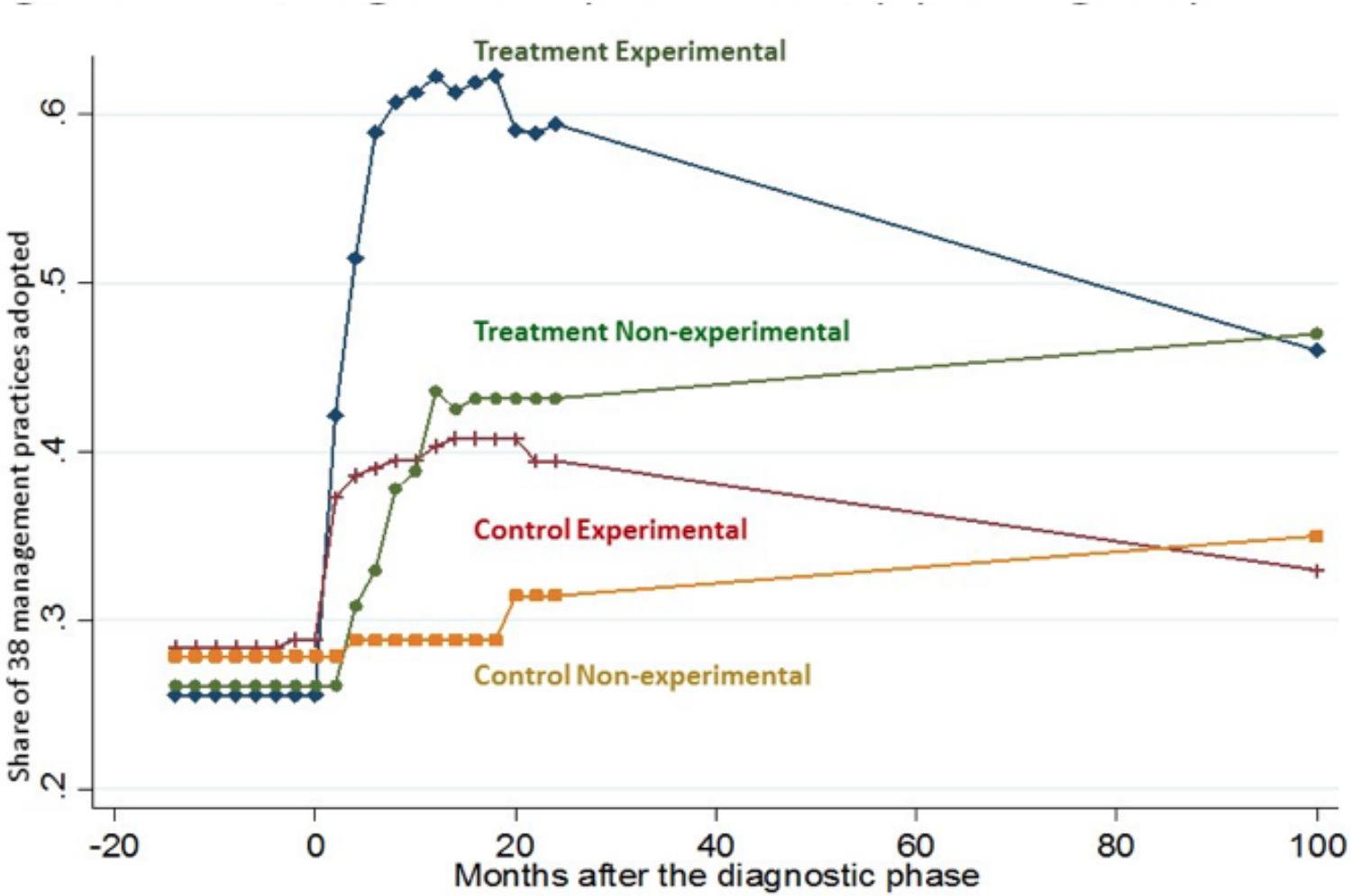
$$Outcome_{i,t} = \alpha_i + \beta_t + \theta Management_{i,t} + \nu_{i,t}$$

Dep. Var.	Quality Defects	Quality Defects	Invent.	Invent.	Output	Output	TFP	TFP
Specification	OLS	IV	OLS	IV	OLS	IV	OLS	IV
$Management_{i,t}$	-0.561	-1.675**	-0.639***	-0.921***	0.127	0.320**	0.160	0.488**
	(0.440)	(0.763)	(0.242)	(0.290)	(0.099)	(0.118)	(0.179)	(0.227)
1st stage Fstat		67.51		63.76		91.20		74.68
Time FEs	113	113	113	113	114	114	113	113
Plant FEs	20	20	18	18	20	20	20	20
Observations	1732	1732	1977	1977	2312	2312	1779	1779

Standard errors bootstrap clustered by firm.
The IV for management is cumulative weeks of treatment.

The interventions last

- Follow-up eight years later in a separate paper



Why don't these firms improve themselves?

- Asked the consultants to investigate the non-adoption of each of the 38 practices, in each plant, every other month
- Did this by discussion with the owners, managers, observation of the factory, and from trying to change management practices.
- Find this is primarily an information problem
  - Wrong information (do not believe worth doing)
  - No information (never heard of the practices)

Why doesn't competition fix this?

Why doesn't competition fix this?

- Entry appears limited: capital intensive due to minimum scale (for a warping loom and 30 weaving looms at least $1m)
- Trade is restricted: 50% tariff on fabric imports from China
- Reallocation appears limited: owners take all decisions as they worry about managers stealing. But owners time is constrained – they already work 72.4 hours average a week – limiting growth of successful firms. As a result firm size is more linked to number of male family members (corr=0.689) than management scores (corr=0.223)

Summary

- Management matters in Indian firms – large impacts on productivity and profitability from more modern practices
- A primary reason for bad management appears to be lack of information, which limited competition allows to persist
- Policy implications?
  - A) Competition and FDI: free product markets and encourage foreign multinationals to accelerate spread of best practices
  - B) Training: improved basic training around management skills
  - C) Rule of law: improve rule of law to encourage reallocation and ownership and control separation