Organizational Barriers to Technology Adoption: Evidence from Soccer-Ball Producers in Pakistan

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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:
    - Mansfield (1961): 12 major industrial technologies.
    - Bloom et al. (2013): management practices.
  - Rosenberg (1972):

    > "[I]f 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."
- 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.

Our Setting

- This project studies adoption among 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:
  1. Large number of firms (135) producing standardized product using same, simple production process.
  2. We discovered a useful innovation: a new way of cutting pentagons (details coming).
     - Allows us (a) to generate experimental variation in access to/knowledge about new technology and (b) to observe adoption very accurately.

First Experiment: Tech Drop

- Our main original objective was to focus on spillovers:
  - Expected rapid take-up among treated firms.
  - Collected information on network links at baseline.
  - Introduced technology to a random subset of firms.
  - Planned to:
    - Look at direct effects of treatment, heterogeneity in impacts.
    - Relate adoption by control firms to fraction of network links to treated firms (Miguel and Kremer, 2004; Duflo and Saez, 2003).
- Technology allocated to subset of firms in May 2012.
  - Tech drop: 35 firms.
  - Control: 97 firms (18 Cash drop, 79 No drop).

Early Finding: Puzzlingly Low Adoption

- Take-up has been sufficient to indicate (to us) that our technology is working, but is still puzzlingly low.
  - 6 firms had adopted (i.e. had produced >1,000 balls with new die in previous month) by Aug. 2013.
- Objective of this paper: investigate why adoption has been so limited among tech-drop firms.
- We are exploring spillovers in a companion project.

Hypothesis: Conflict of Interest within Firm

- Main reason cited by firms for non-adoption: employee resistance.
- We 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.
- We formalize this intuition in a simple principal-agent model with strategic communication.
  - Linear wage contracts (not conditioned on marginal cost, a characteristic of the technology revealed ex post) $\rightarrow$ agent misinforms and principal does not adopt.
  - Contract conditioned on marginal cost (at some fixed cost) $\rightarrow$ agent reveals truthfully and principal adopts.

Second Experiment: Incentive Payment

- Among original tech-drop firms, we randomly offered a one-time incentive payment to employees.
  - Payment was conditional on the employee demonstrating competence with new technology in front of owner.
- Incentives small from point of view of firm:
  - \$150 and \$120 vs. median cost savings ∼\$6000/yr (on median revenues of ∼\$360,000/yr.)
- Incentive-payment intervention had significant positive effect on adoption.
  - Adoption probability ↑ 26-32% among firms offered treatment, depending on specification.
- Numbers are small (sample size: 31), but the significant effect on adoption suggests that organizational barriers are an important constraint.

Related Literature

- Descriptive literatures on worker resistance:
  - In piece-rate systems, worker conceal information about how fast they can work (Taylor, 1911; Mathewson, 1931; Edwards, 1979; Clawson, 1980).
    - Not about technologies from outside the firm.
  - Workers resist labor-saving technologies (Lazonick, 1979, 1990; Mokyr, 1990).
    - Our technology is labor-*using*.
    - No unions/guilds in Sialkot.
  - Recent case study: Freeman and Kleiner (2005).
- Alternative explanations for slow adoption in manufacturing:
  - Lack of competitive pressure: Bloom and Van Reenen (2007, 2010), Bloom et al. (2013) Schmitz (2005).
    - Almost all sales on export markets which appear quite competitive.
  - Need for complementary innovations: Rosenberg (1982), David (1990), Bresnahan and Trajtenberg (1995).
    - Our technology requires minimal changes to other aspects of production.

Related Literature (cont.)

- Active literature on technology adoption in agriculture:
  - Ryan and Gross (1943), Griliches (1957), Rogers (1962), Foster and Rosenzweig (1995), Bandiera and Rasul (2006) Conley and Udry (2010), Suri (2011) Duflo, Kremer and Robinson (2011), Hanna et al. (2012), BenYishay and Mobarak (2014).
  - Our setting is different, and interesting, because:
    - non-atomistic decision-makers
    - less noise in production and frequent signals
    - less risk-averse decision-makers
    - arguably greater competitive pressure.

Related Literature (cont.)

- Field Experiments in Firms:
  - Bandiera, Barankay and Rasul (2005, 2007, 2009)
  - de Mel, McKenzie and Woodruff (2008)
  - Bloom, Eifert, Mahajan, McKenzie and Roberts (2013)
    - Emphasize "informational constraints" in addition to lack of competition.
    - Our study provides a possible micro-foundation for "informational contraints" idea.

Related Literature (cont.)

- Literature on organizations:
  - Strategic communication: Crawford and Sobel (1982), Sobel (2013).
  - Contracting: Gibbons (1987), Lazear (1986), Holmstrom and Milgrom (1991), Milgrom and Roberts (1995).
  - "Organizational failures": Garicano and Rayo (2016), Dow and Perotti (2013).
  - Not aware of previous model of workers on piece rates dissuadng employers from adopting surplus-enhancing technologies through cheap talk.
  - But main contribution to organizations literature is to explore mechanisms in experimental setting, as opposed to cases.

Outline of Talk

1. Introduction
2. The Industry/Our Technology
3. Experiment I: Tech Drop
4. Brief Summary of Model
5. Experiment II: Incentive Payment
6. Conclusion

Setting: Soccer-Ball Cluster in Sialkot, Pakistan

- ∼30 million balls/year, almost all exported.
- 40% of world production, 70% within hand-stitched segment (WSJ, 2010).
- 5-10 large firms (250+ employees):
  - Produce high-quality name-brand balls for Adidas (including 2014 World Cup ball), Nike etc.
- Fringe of small/medium-sized firms:
  - Find clients at industry expos, Alibaba or subcontract locally.
  - Produce low-quality "promotional" balls or mid-quality "training" balls.

1st Stage: Glue Cotton/Polyester to Artificial Leather

2nd Stage: Cut Hexagons and Pentagons

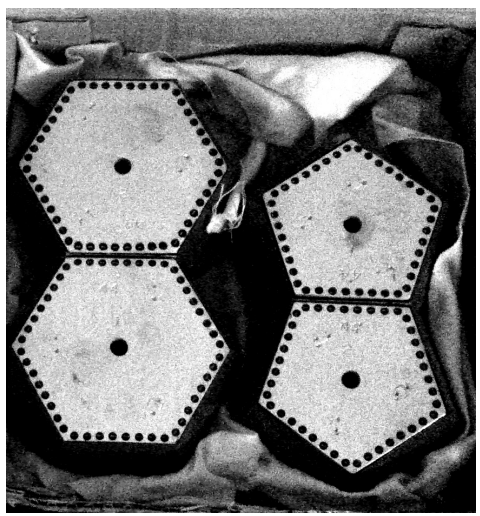
3rd Stage: Print Logos/Designs on Panels

4th Stage: Stitch Panels around Bladder

Existing Cutting Technology

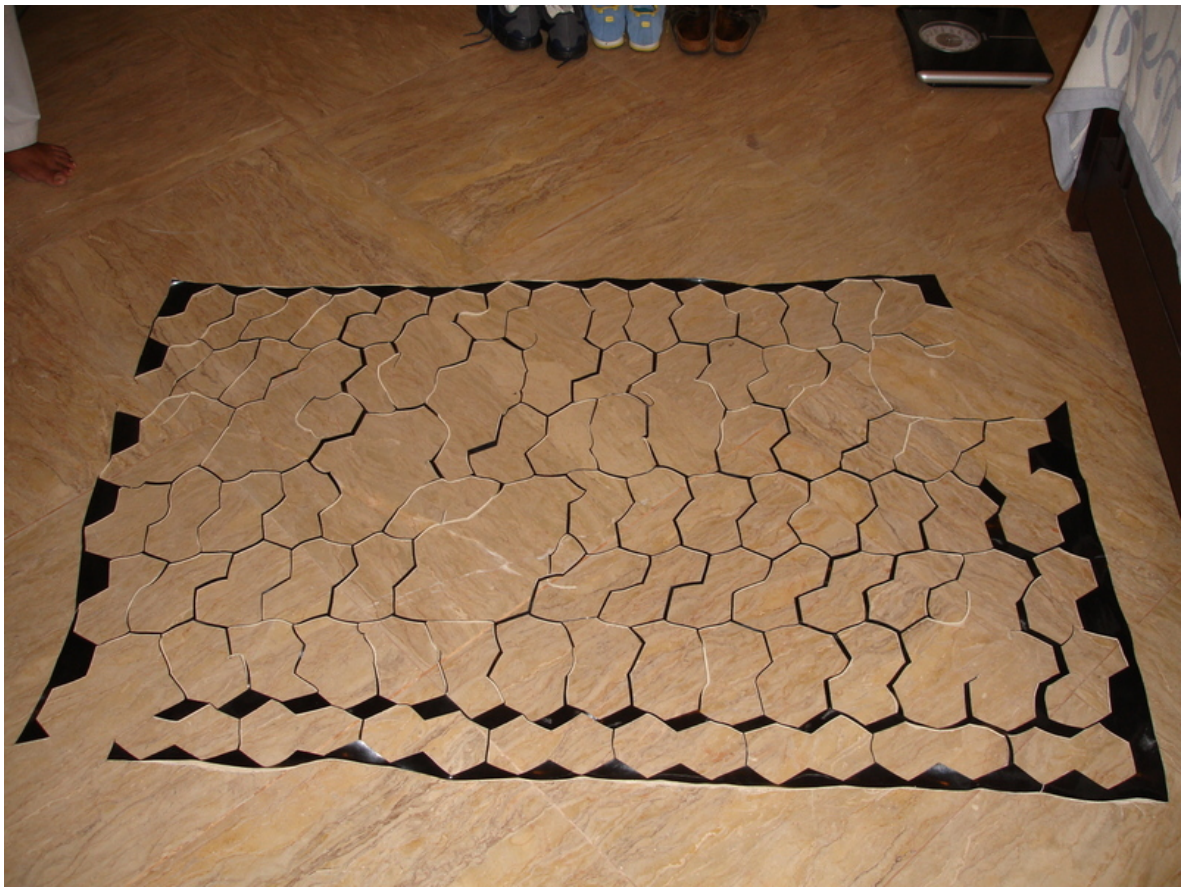
Standard "buckyball" design: 20 hexagons, 12 pentagons.

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



Existing Cutting Technology (cont.)

Hexagons tessellate. $\sim$ 8% of rexine wasted.



Existing Cutting Technology (cont.)

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

Origin of Idea

In a YouTube video of a Chinese factory producing the Adidas Jabulani ball, I noticed a different layout of pentagons.

Origin of Idea (cont.)

We could also have gone to: G. Kuperberg and W. Kuperberg, "Double-Lattice Packings of Convex Bodies in the Plane," *Discrete & Computational Geometry*, 5: 389-397, 1990.

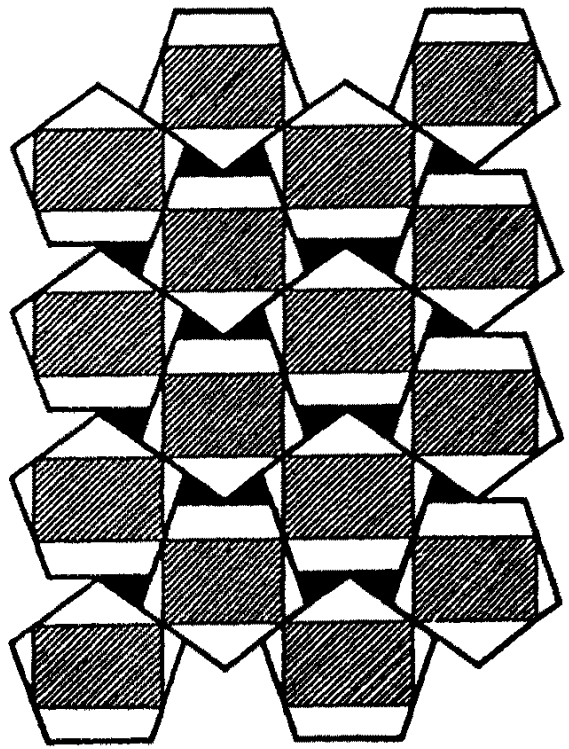
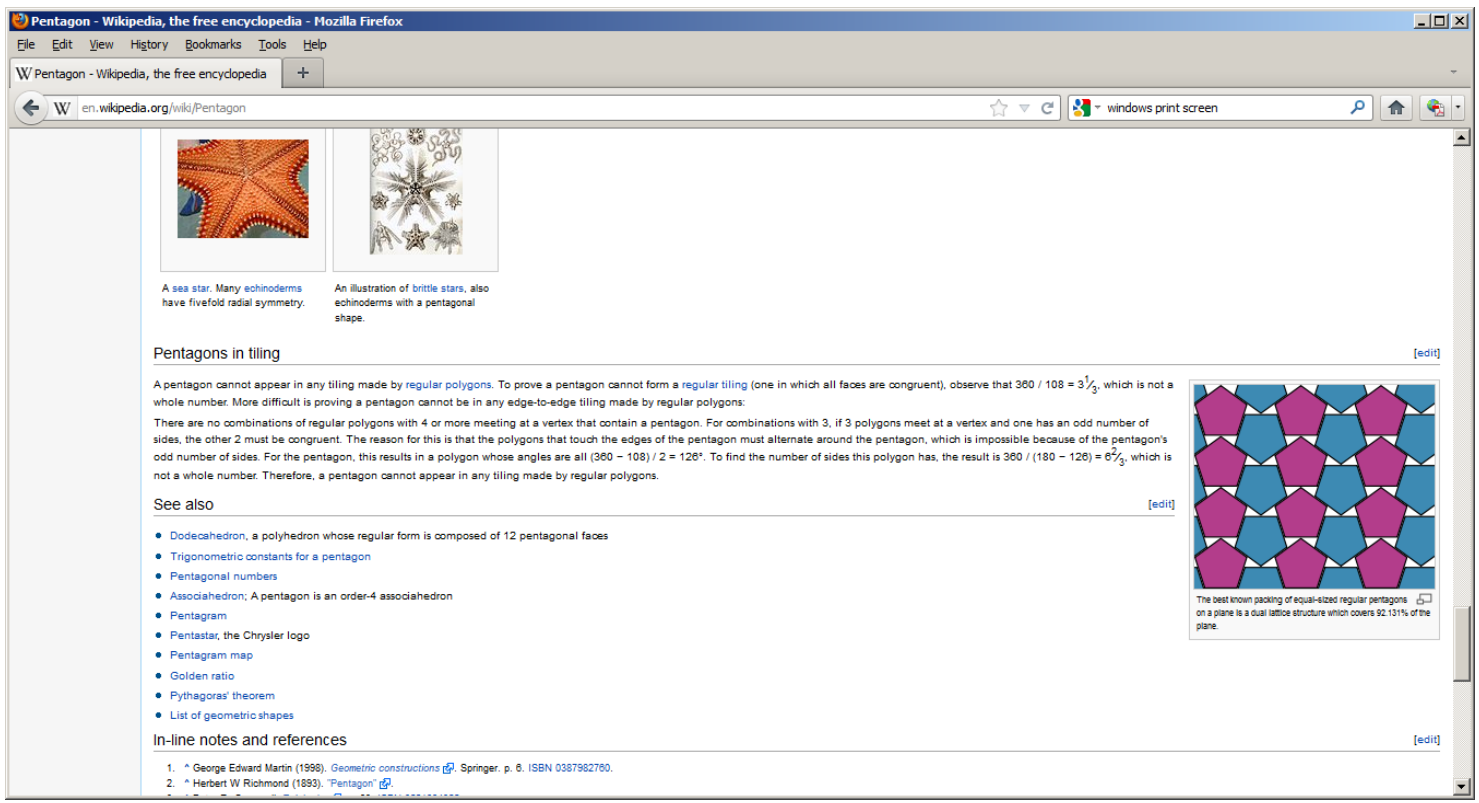


Fig. 7. Maximum density double-lattice packing with regular pentagons.

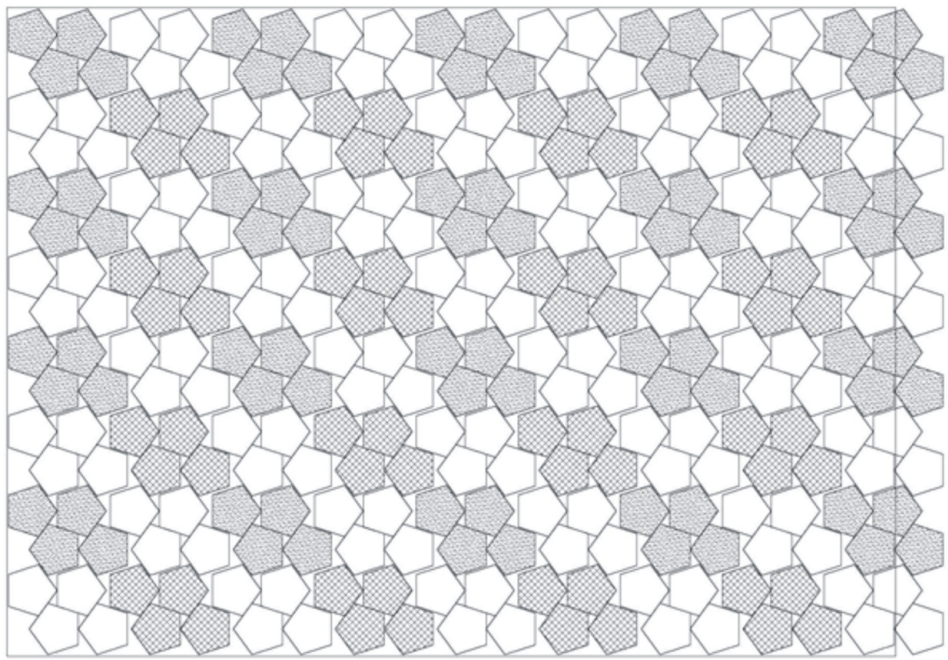
Origin of Idea (cont.)

Or the Wikipedia Pentagons page:



Blueprint

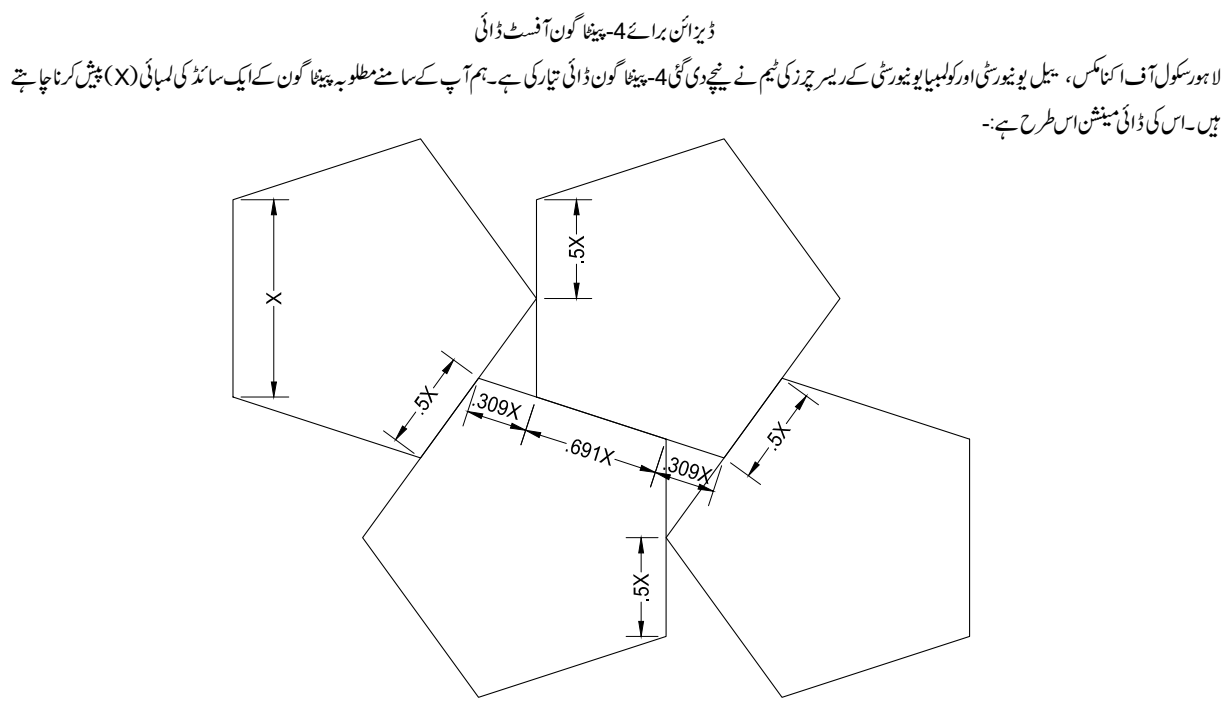
Annalisa Guzzini (an architect, my wife) and I developed a blueprint for a 4-pentagon die to implement the optimal packing.



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

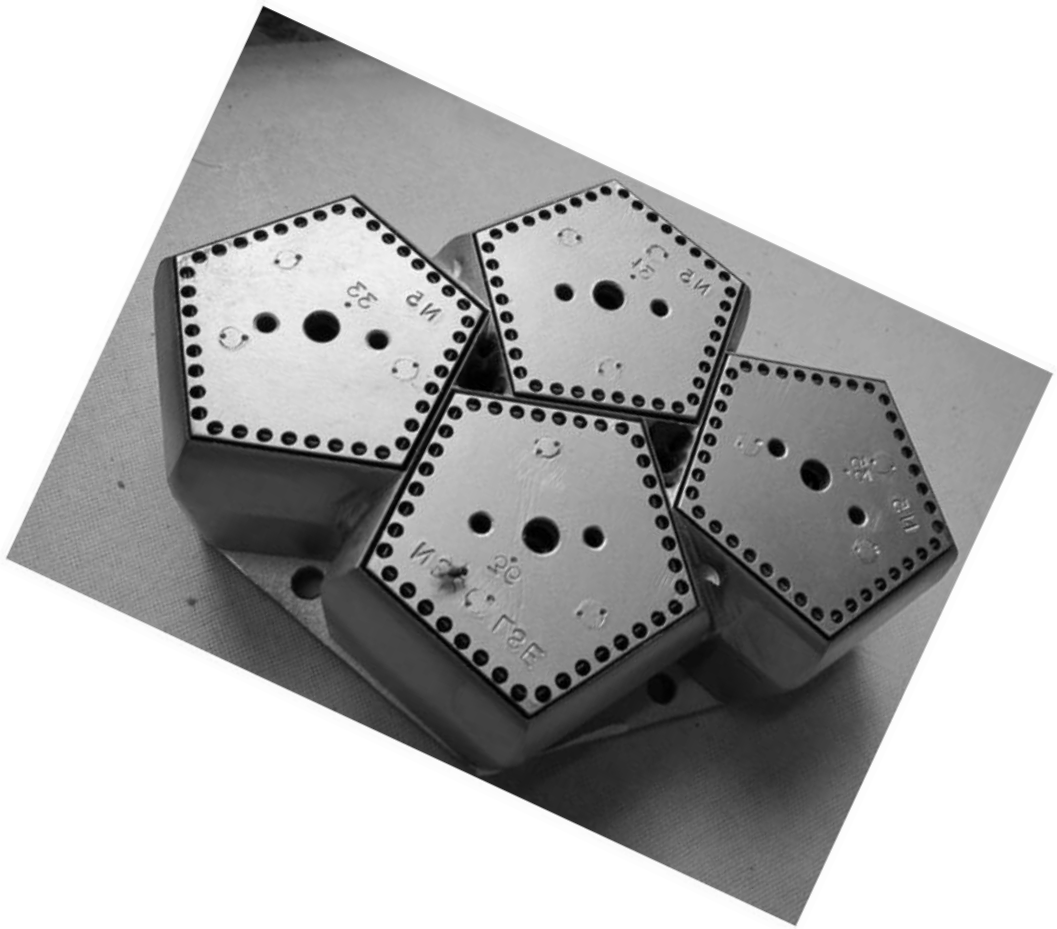
Blueprint (cont.)

Blueprint includes instructions for modifying size of die.



- Sides of adjacent pentagons are "offset," not flush.
- 4-pentagon pattern can be replicated by two 2-pentagon cuts.
  - We will also consider a two-piece offset die as our technology

The "Shamyla" Die



Net Variable Cost Reduction from Offset Die (Table II)

- Values for median firm.
- Cost reduction from reduced rexine wastage:

Cost reduction per pentagon:	6.76%
Pentagons as share of rexine sheet cost:	33%
Rexine sheet cost as share of total cost:	44.83%
Estimated total cost reduction (6.84 % × 33% × 44.7%):	**.98%**

- Additional labor costs:

Increase in pentagon cutting time (conservative):	100%
Pentagons as share of cutting time:	33%
Cutting as share of total costs	.45%
Estimated total cost increase (50% × 33% × .46%):	**.15%**

- Net variable cost reduction: ∼.82%.
  - Small, but 10.6% of profits

Fixed Costs

- Die sizes vary, may need to be purchased for new order.
  - 2-pentagon die now costs 10,000 Rs (US$100).
- Printing screens have to be re-designed, re-made.
  - Designers charge ∼600 Rs (US$6) for each design.
  - Outside screenmakers charge ∼200 Rs (US$2).
- May need to purchase offset "combing" dies (to punch holes in edges for sewing.)
  - Cost: ∼10,000 Rs (US$100).
  - Can use single-pentagon die, but slower.
- **Estimate of total fixed cost: US$208 per cutter.**
  - Conservative, in that many firms do not use combing machine, and would have to order new designs/screens in any case.
  - If die received free, fixed cost estimate: US$108 per cutter.

Table II: Net Benefits of Adoption

	10^{th}	25^{th}	**50^{th}**	75^{th}	90^{th}	mean
net variable cost reduction (%)	0.42	0.61	0.82	1.09	1.47	0.89
	(0.11)	(0.10)	(0.09)	(0.19)	(0.27)	(0.11)
% net variable cost/avg % profit rate	4.55	6.82	10.63	16.56	24.42	13.07
	(1.05)	(1.13)	(1.60)	(2.35)	(4.15)	(1.79)
total cost savings per month (Rs 000s)	3.66	9.82	41.35	135.92	397.95	137.77
	(0.99)	(2.33)	(9.43)	(36.39)	(130.62)	(31.68)
total cost savings per cutter per month (Rs 000s)	2.75	6.47	14.91	33.83	63.61	27.31
	(0.83)	(1.33)	(2.43)	(6.28)	(14.02)	(5.04)
days to recover fixed costs	10.28	19.11	43.03	100.86	247.53	168.80
	(2.23)	(3.66)	(7.37)	(21.74)	(76.42)	(84.72)
days to recover fixed costs (no die)	5.34	9.92	22.34	52.37	128.53	87.64
	(1.16)	(1.90)	(3.83)	(11.29)	(39.68)	(43.99)

- **We estimate that 50% of tech drop firms would recover fixed costs in 23 days or less, 75% in 53 days or less.**
- Will consider possibility of unobserved fixed costs later in talk.

Measuring Adoption

- Issues:
  - Some firms report experimenting, but not using for an order.
    - Count as adopter? No. Minimum 1,000 balls with new die. (Not sensitive to cut-off.)
  - Demand is very volatile, especially for small/medium firms.
    - Count if *ever* produced >1,000 balls with new die.
  - Surveys ask only about previous month (to avoid recall bias). Our enumerators have communicated with firms between rounds.
    - "Liberal" adoption measure: use between-round information.
    - "Conservative" measure: do not use.

Tech Drop Experiment: Design

3 groups:

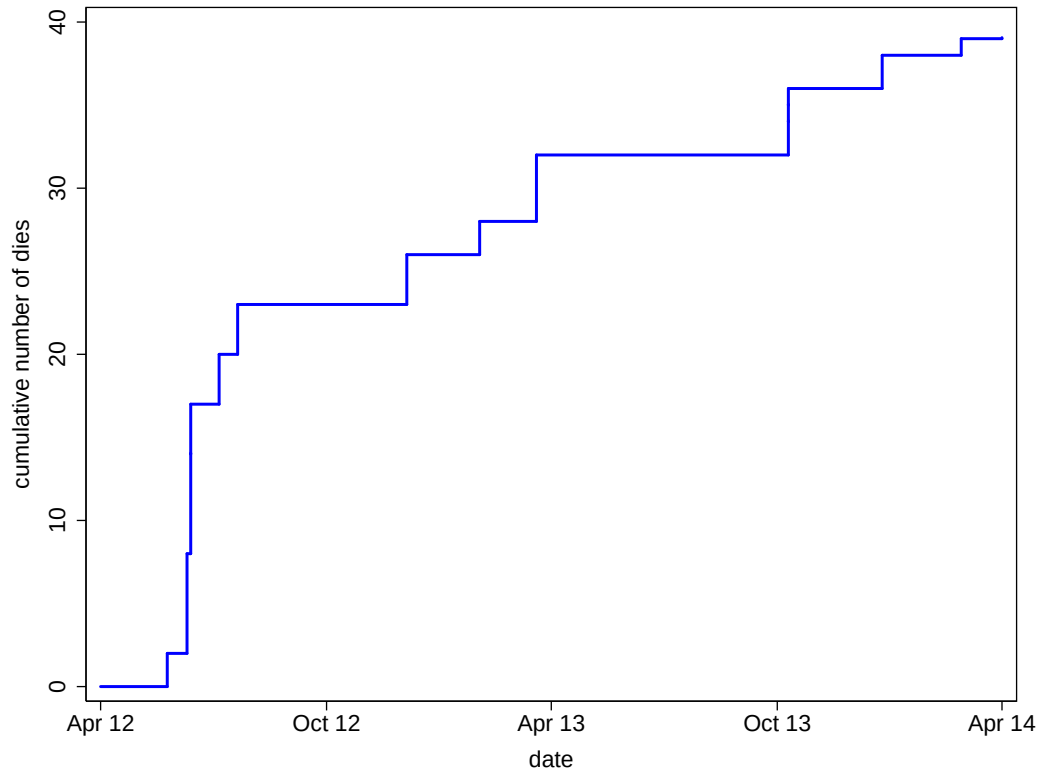
1. Tech drop:
   - Die + blueprint.
   - 30 min. demonstration, including comparison to existing die.
   - Offer to trade in die for different size at no cost.
     - Panel sizes vary, even for a given size ball.
     - To be usable, pentagon die has to be exactly same size as hexagon die.
2. Cash drop:
   - 30,000 Rs cash ($\sim$ US$300) — the amount we paid for each die.
3. "No drop"
   - No intervention.

Dropped technology in May-June 2012. Surveys approx. every 3 months since then.

Table V: Adoption as of Aug. 2013

	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

Die Purchases by Firm Z



- Second-largest by employment in Sialkot (∼2,200 employees).
- No-drop group, late responder.
- As of March 2014, using offset die for ∼100% of production.

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 significantly associated with adoption (although numbers are small).
- No significant associations 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.

Motivation for Model

- In Round 4 (March-April 2013), we asked firms who had an offset die but were not currently using it:

  Please select the main reason(s) why you are not currently using an offset die. If more than one, please rank those that apply in order (1 for most important, 2 for second-most important etc.)

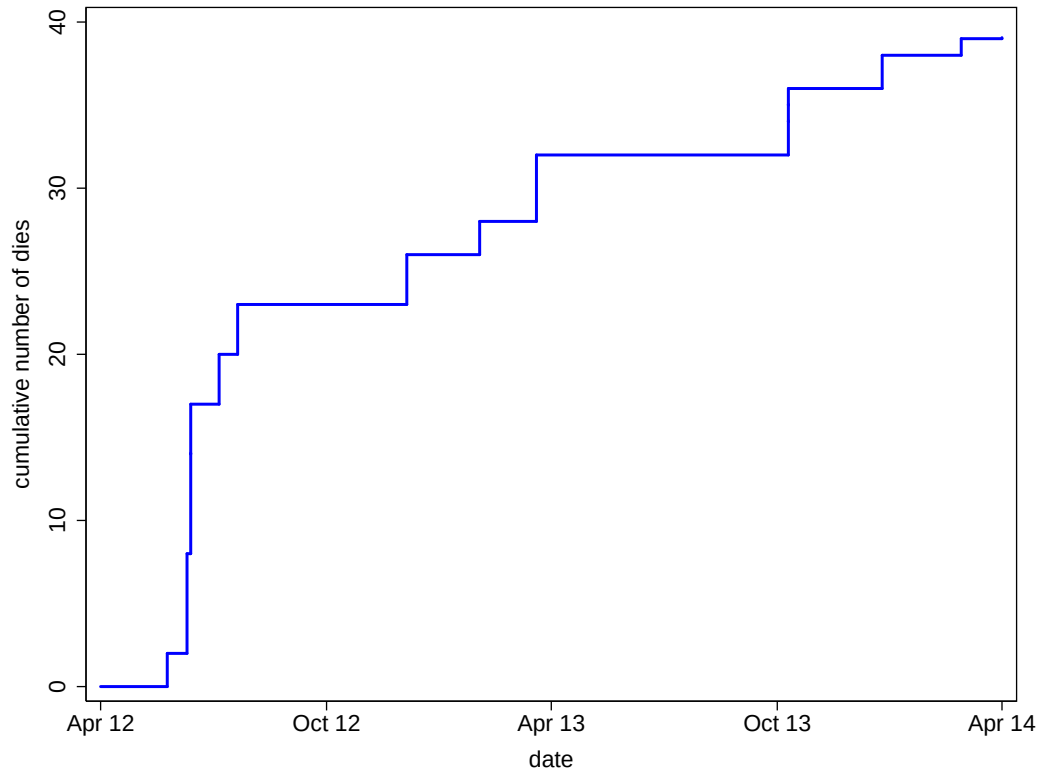
  a. *I have not had any orders to try out the offset die.*
  b. *I have been too busy to implement a new technology.*
  c. *I do not think the offset die will be profitable to use.*
  d. *I am waiting for other firms to adopt first to prove the potential of the technology.*
  e. *I am waiting for other firms to adopt first to iron out any issues with the new technology.*
  f. **The cutters are unwilling to work with the offset die.**
  g. *I have had problems adapting the printing process to match the offset patterns.*
  h. *There are problems adapting other parts of the production process (not printing or cutters willingness)*
  i. *Other [fill in reason]*

Table VI: Reasons for Non-Adoption

firm	no orders to try on	too busy	doubt profitable	waiting for others to prove value	waiting for others to iron out kinks	cutters unwilling	printing problems	other production issues	other
1	2	3					1		
2	2						1		
3	2						1		
4	2						1		
5	2					1			
6	4		3			1	2		
7	3		2			1			
8	3					1	2		
9	3	2				1			
10	1								
11	1								
12	1								
13	3					1	2		
14	3					1	2		
15	2					1			3
16	1								
17	5	3				1	2	4	
18	2	3				1			3

- Numbers indicate order of importance indicated by respondent.
- Sample is round-4 respondents who have had die in their factory but are not currently using it.

Die Purchases by Firm Z Redux



- Second-largest by employment in Sialkot (∼2,200 employees).
- No drop group, late responder.
- As of March 2014, using offset die for ∼100% of production.
- *Pays monthly salary to cutters, not piece rate.*

Anecdote I

- In one of the refusers, owner deferred to cutter, but cutter refused. Report from our enumerators:

  > *[The cutter] explained that the owner will not compensate him for the extra panels he will get out of each sheet. He said that the incentive offer of PKR 15,000 is not worth all the tensions in future.*

Anecdote II

- From one of 10 accepters:

  [The owner] told us that the firm is getting only 2 to 4 extra pentagon panels by using our offset panel... The owner thinks that the cost savings are not large enough to adopt the offset die.... He allowed us to time the cutter.

  On entering the cutting area, we saw the cutter practicing with our offset die... We tested the cutter (the owner wasn't there). He got 279 pentagon pieces in 2 minutes 32 seconds... The cutter privately told us that he can get 10 to 12 pieces extra by using our offset die.

  We informed the owner about the cutter's performance. The owner asked the cutter how many more pieces he can get by using the offset die. The cutter replied, "only 2 to 4 extra panels."

  The owner asked the cutter to cut a sheet in front of him. The cutter got 275 pieces in 2 minutes 25 seconds. The owner looked satisfied by the cutter's speed...

  The owner requested us to experiment with volleyball dies.

Anecdote III

- In another refuser, owner reported that he had modified labor contract in order to adopt:

  [The owner] said that it takes 1 hour for his cutter to cut 25 sheets with the conventional die. With the offset die it takes his cutter 15 mins more to cut 25 sheets for which he pays him pkr 100 extra for the day which is not a big deal.

  - This owner has not been willing to answer surveys and we have not be able to confirm that he has adopted, by our definition.

A Model of Organizational Barriers to Adoption

- Key questions:
  - Why are owners influenced by cutters, given that they should be aware that cutters may have an incentive to resist adoption?
  - Why do owners not simply change labor contract?
- Principal-agent model with non-contractible effort, limited liability.
- Basics:
  - Agent produces output $q = se$, where s is speed of technology and e is effort (non-contractible).
  - Agent faces effort cost: $\frac{e^2}{2}$.
  - Materials cost: $C(q) = cq$
  - Principal's payoff: $pq - cq - w(q)$
- Wage contracts:
  - Assumed initially to be of the form: $w(q) = \alpha + \beta q$.
  - Limited liability: $\alpha \geq 0$. Agent can't be made to pay for job.

Set-up (cont.)

- Technology:
  - Existing technology has speed s_0, cost per unit c_0.
  - New technology is one of 3 types:

    θ_1: $c_1 = c_0$, $s_1 < s_o$: Dominated by existing technology (slower).

    θ_2: $c_2 < c_0$, $s_2 < s_0$: Material saving technology (our technology).

    θ_3: $c_3 = c_0$, $s_3 > s_0$: Labor saving technology (e.g. the two-piece die).
  - Agent knows type.
  - Principal has priors: ρ_1, ρ_2, ρ_3, with $\sum_{i=1}^{3} \rho_i = 1$.
  - Fixed cost of adoption of any new technology: F.
- We restrict to region of parameter space where:
  - Principal would want to adopt type θ_2 and θ_3 (but not θ_1), if she knew type.
  - Based only on her priors, she would not adopt.

Set-up (cont.)

- Timing:
  - Stage 1: Principal chooses wage contract.
  - Stage 2: Nature reveals technology type to agent.
  - Stage 3: Agent sends message to agent about technology.
  - Stage 4: Principal adopts or not.
  - Stage 5: Payoffs realized.

Imperfectly Informed Principal, No Conditional Contract

- *Proposition 1: If conditional contracts are not available, the following are part of a perfect Bayesian equilibrium.*
  - *Agent's strategy:*
    - *say "technology is bad" if the technology is type θ_1 or θ_2.*
    - *say "technology is good" if the technology is type θ_3.*
  - *Principal's strategy:*
    - *Offer wage contract* $\left(\alpha^* = 0, \beta^* = \frac{p - c_0}{2}\right)$
    - *adopt if the agent says "technology is good".*
    - *do not adopt if the agent says "technology is bad".*
- Intuition:
  - Given a fixed-ex-ante piece rate, agent prefers non-adoption to slower technology so will discourage adoption if type θ_2.
  - If Principal hears "technology is bad" she infers "type θ_1 or θ_2." Given priors (and parameter restrictions), does not adopt.
  - Why is principal influenced by agent's message knowing he will lie about type θ_2?
    - Interests are aligned for types θ_1 and θ_3. Advice from agent useful in expectation.

Imperfectly Informed, No Conditional Contracts (cont.)

Two additional results proved along the way:

- Lemma 1 (paraphrased): In the subgame for any given β, there are just two types of possible equilibria:
  - An "informative equilibrium", in which the principal's action varies with the message received from the agent, where
    - agents who observe θ_1 or θ_2 send most discouraging possible message.
    - agents who observe θ_3 send most encouraging possible message.
  - A "babbling equilibrium" in which the principal ignores the agent's message.
  - N.B.: there is no equilibrium where agent encourages adoption of type θ_2.
- Equilibrium in Proposition 1 is the "most informative".
  - Under restriction that players are always able to coordinate on informative subgame equilibrium (when it exists), equilibrium is unique.

Imperfectly Informed, Conditional Contracts

- Now assume principal can pay fixed cost, G, to condition contract on marginal cost c (observed after adoption):

$$w(q) = \alpha + \beta q + \gamma q \qquad \text{if } c = c_2$$

$$w(q) = \alpha + \beta q \qquad \text{if } c \neq c_2$$

Imperfectly Informed, Conditional Contracts

- *Proposition 2: Under conditional contracts, the following set of strategies is part of a PBE:*
  - *Principal's strategy:*
    - *If*

$$G < \rho_2 \left[\pi_2(\beta_2) - \pi_0(\beta_0)\right] \tag{1}$$

      then pay G, offer schedule:
      $\left(\alpha^{**} = 0, \beta^{**} = \frac{p - c_0}{2}, \gamma^{**} = \frac{c_0 - c_2}{2}\right)$
    - *If (1) does not hold, then do not pay G, offer*
      $\left(\alpha^{**} = 0, \beta^{**} = \frac{p - c_0}{2}\right)$
    - *Adopt if agent says "technology is good"; do not adopt if agent says "technology is bad".*
  - *Agent's strategy:*
    - *If principal pays G: say "technology is good" if type θ_2 or θ_3; say "technology is bad" if type θ_1.*
    - *If principal does not pay G: say "technology is good" if type θ_3; say "technology is bad" if θ_1 or θ_2.*

Model: Discussion

- Equilibrium exists where employees misinform owners about material-saving technologies.
  - Conditioning contracts on ex-post-revealed characteristics of technology can solve misinformation problem.
- Why might principal not adopt the conditional contract?
  - Principal just not aware of alternative contract.
    - World of Proposition 1.
  - Principal aware of contract, expected benefit less than cost G.
    - Cost may be high because employment contracts custom-bound and hard to change, or optimally sticky given previous labor-saving innovations (e.g. the two-piece die).
    - Or expected benefit low if owner has pessimistic priors.
- Key point is that most firms did not adjust contract, which left scope for our incentive intervention to have an effect.

Incentive-Payment Experiment: Design

Randomly assign still-active tech-drop firms to:

A. Incentive group:
   - Refresher about technology. Offer repeat of demonstration. Mention 2-pentagon die.
   - Incentive treatment:
     - 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 (272 pentagons in 3 min. for cutter, 48 2-pentagon swipes in 3 min. for printer) 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:
   - Refresher about technology, offer repeat of demonstration, mention 2-pentagon die.

Table VII: Covariate Balance, Incentive-Payment Exp.

	Group A Incentive Payment	Group B No Incentive Payment
log avg output/month	9.86	9.31
	(0.41)	(0.29)
log avg employment	3.35	3.23
	(0.38)	(0.25)
log avg price, size 5 promo	5.40	5.45
	(0.02)	(0.07)
log avg price, size 5 training	6.00	5.93
	(0.06)	(0.06)
avg % promotional (of size 5)	34.90	32.04
	(6.20)	(7.26)
avg Rs/ball, head cutter	1.45	1.63
	(0.10)	(0.15)
CEO university indicator	0.56	0.36
	(0.18)	(0.15)
CEO experience	15.50	16.50
	(3.60)	(3.60)
age of firm	24.53	20.60
	(2.83)	(2.28)
N	15	16

- No differences significant at 5% level.
- As of Aug. 2013, we believed there were 34 active tech drop firms, and randomized 17 firms each into groups A and B. Three were subsequently revealed to have closed and/or stopped producing soccer balls.

Incentive Payment Experiment: Summary

- Of the 15 active Group A (Incentive Payment) firms:
  - 5 refused intervention
  - 10 accepted (2 were already adopters)
    - All passed, average time 2:52 (vs 2:15 traditional)
  - Of the 8 accepters who had not yet adopted:
    - 5 adopted (liberal measure); 4 (conservative measure). All within 6 months.
    - 3 (not strict subset) purchased their first offset die (beyond trade-in).
- Of the 16 active Group B (No Incentive) firms:
  - 3 were already adopters.
  - Of 13 initial non-adopters:
    - None adopted in first 6 months.
    - One adopted in next 6 months (by either measure).
    - No new die purchases.

Table VIII: Adoption as Outcome (Liberal Measure)

	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

- Small-sample-robust permutation test:
  - Calculate ITT for all possible (25.8m) treatment assignments.
  - Reject null if our estimate lies e.g. outside 2.5^{th}, 97.5^{th} percentile.

Table IX: Adoption as Outcome (Cons. Measure)

	First Stage (1)	OLS (2)	Reduced Form (ITT) (3)	IV (TOT) (4)
Panel A: Short-Run (within 6 months)				
received treatment		0.45***		0.46***
		(0.16)		(0.16)
assigned to group A	0.68***		0.31**	
	(0.12)		(0.12)	
stratum dummies	Y	Y	Y	Y
mean of group B (control group)		0.12	0.12	0.12
R-squared	0.57	0.56	0.46	0.56
N	31	31	31	31
Panel B: Medium-Run (within 1 year)				
received treatment		0.39**		0.35*
		(0.17)		(0.19)
assigned to group A	0.72***		0.26*	
	(0.12)		(0.14)	
stratum dummies	Y	Y	Y	Y
mean of group B (control group)		0.20	0.20	0.20
R-squared	0.60	0.46	0.38	0.45
N	29	29	29	29

Table X: Die Purchase as Outcome

	First Stage (1)	OLS (2)	Reduced Form (ITT) (3)	IV (TOT) (4)
Panel A: Short-Run (within 6 months)				
received treatment		0.42**		0.40**
		(0.15)		(0.16)
assigned to group A	0.68***		0.27**	
	(0.12)		(0.12)	
stratum dummies	Y	Y	Y	Y
mean of group B (control)		0.00	0.00	0.00
R-squared	0.57	0.40	0.24	0.40
N	31	31	31	31
Panel B: Medium-Run (within 1 year)				
received treatment		0.41**		0.38**
		(0.15)		(0.16)
assigned to group A	0.72***		0.28**	
	(0.12)		(0.12)	
stratum dummies	Y	Y	Y	Y
mean of group B (control)		0.00	0.00	0.00
R-squared	0.60	0.40	0.24	0.40
N	29	29	29	29

Corroborating Evidence

Additional evidence from most recent survey round:

- Sticky Wages:
  - 10/24 tech-drop respondents did not change head cutter wage Aug 2013-Sept 2014. Those that did cite inflation and "end of year" change.
  - 1/24 changed because of offset die. Firms say changing scheme would violate norms. Cutters say not their place to suggest changes.
- Information flows:
  - Asked owners about conversations with employees about die.
  - Question not perfect: of 10 who reported "cutters unwilling" (Table VI), only 6 reported having conversation.
  - 10/22 discussed offset die adoption with head cutter.
    - In 3 cases where cutter positive, all adopted.
    - In 6 cases where cutter negative, 4 did not adopt, 2 adopted (liberal def.). (5/1 with conservative def.)

Corroborating Evidence (cont.)

- The original back-to-back die (faster so no misalignment):
  - First used in 1994. Firms adopted within 6 months of hearing about it.
  - 23/24 respondents report no resistance from cutters.

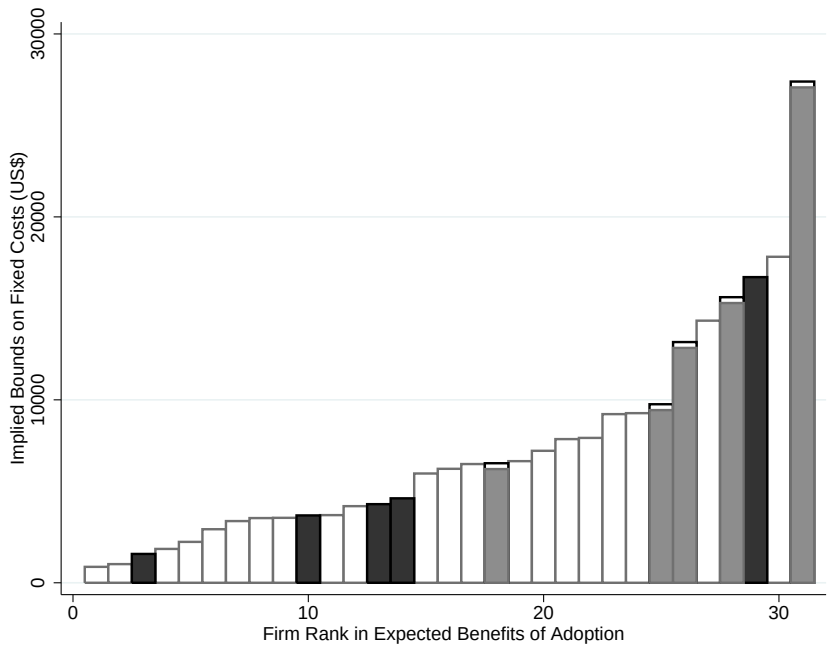
Alternative Explanation #1

- We mechanically induced adoption by subsidizing the (possibly unobserved) fixed costs of adoption.
  - Is this quantitatively plausible?
  - Expression for expected additional profit from adoption:

$$\Pi_f = -F_f + P \sum_{t=1}^{\infty} \frac{NVB_f}{(1+r)^t} \tag{2}$$

    where F_f=fixed costs, P=owner's prior, NVB_f=net variable benefits, r=interest rate.
  - Firms self-report interest rates of 9-25%/year. Take upper bound (conservative).
  - Calculate NVB_f from data.
  - For a given prior, non-adoption ($\Pi_f < 0$) implies lower bound on F_f. Adoption after \$320 subsidy an upper bound.

Figure V: Implied Bounds on Fixed Costs



- Here $P = .5$. (Table XI considers other priors.)
- Solid black bars: upper bounds for initial adopters. White bars: lower bounds for the never-adopters. Solid grey bars/black outlines above: lower/upper bounds for switchers (difference of \$320).
- Key point: \$320 subsidy is small relative to implied lower bound on fixed costs for initial non-adopters.

Alternative Explanation #1 (cont.)

- Suppose:

$$\ln F_f = \mu + \varepsilon_f$$

  where $\varepsilon_f \sim \mathcal{N}(0, \sigma_\varepsilon^2)$
- Use information on adoption from both experiments to estimate μ, σ_ε by maximum likelihood.
- Panel A of Table 14 reports estimates for different priors.
- Simulation to calculate p-values for ≥ 5 new adopters in experiment 2, based on 1,000 draws from $\mathcal{N}(\hat{\mu}, \hat{\sigma}_\varepsilon^2)$
- For $P \geq .05$, very improbable that we would observe both low initial adoption and so many new adopters, given that \$320 is small relative to implied bound on fixed costs from first experiment.
- Moral: to get quantitative action, we need either extremely low priors or changes in owners' beliefs from communication.

Fig. A.15: Simulation of # of New Adopters in Exp. 2

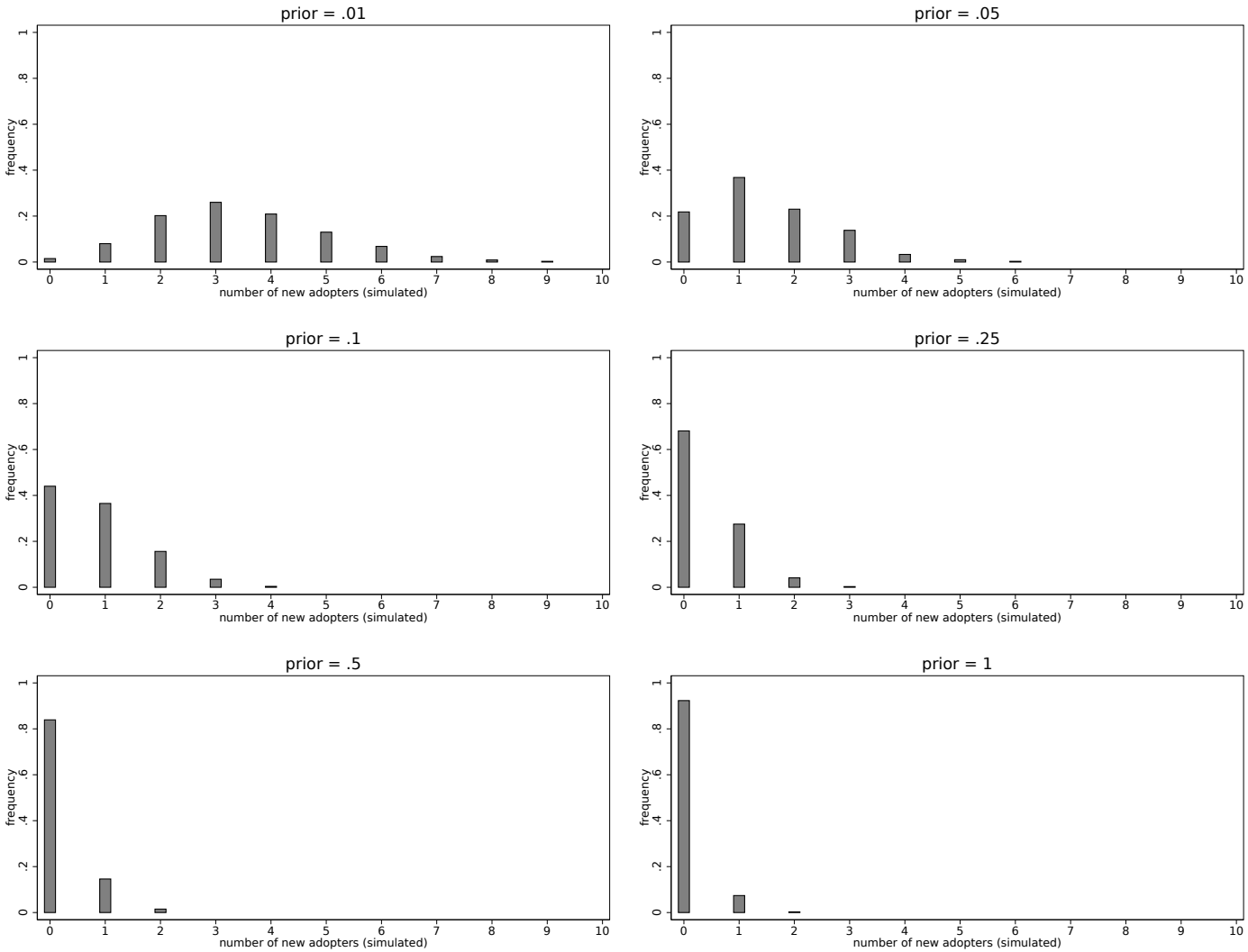


Table XI: Plausibility of Learning-Subsidy Explanation

	Value of prior					
	.01	.05	.1	.25	.5	1
	(1)	(2)	(3)	(4)	(5)	(6)
A. Estimates of fixed costs						
estimate of μ	6.46***	7.41***	8.00***	8.85***	9.53***	10.21***
	(0.50)	(0.30)	(0.29)	(0.28)	(0.28)	(0.28)
estimate of σ_ε	1.87**	1.29**	1.23***	1.21***	1.20***	1.20***
	(0.75)	(0.48)	(0.44)	(0.41)	(0.40)	(0.40)
N	31	31	31	31	31	31
B. ITT estimate						
assigned to group A	0.24	0.10	0.06	0.03	0.01	0.01
	(0.11)	(0.09)	(0.06)	(0.04)	(0.03)	(0.02)
N	31	31	31	31	31	31
C. P-values of observing ≥ 5 adopters in incentive experiment						
	0.234	0.013	0.000	0.000	0.000	0.000

- Uses liberal measure.

Alternative Explanation #2

- The incentive treatment increased the salience of the new technology, and this in itself induced adoption.
  - Simple nudge story unlikely.
    - We also did reminder, offer of demonstration at Group B firms.
  - Alternative story: by putting money on the table we sent stronger signal that we believe technology works.
    - We believe it was clear in initial demonstration that we believed the technology works.
    - We have visited all tech-drop firms, and asked about technology, several times, at a cost to us far exceeding $320.
    - It appears that firms simply believe that we don't know what we are talking about, not that we don't hold our beliefs strongly.

Conclusion

- 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.
- Puzzle: why didn't firms just adjust labor contracts?
- Theory, qualitative evidence suggest two explanations:
  - Changing payment scheme is costly.
    - Given low estimate of benefits (i.e. low prior), even small cost of adjusting contracts may not be worthwhile.
  - Owners didn't happen to think of organizational innovation, or did not understand the need for them.
    - Observationally equivalent to high cost of adopting new contracts, G.
- Key point is that most firms did not adjust, which left scope for our incentive intervention to have an effect.

Conclusion (cont.)

- Some tentative generalizations:
  - Most directly: we would expect similar difficulties in adoption of material-saving, labor-using technologies in settings with piece-rate contracts.
  - Inertia in labor contracts hinders technological change.
    - Piece rates may be optimal in technologically stable environments but not dynamic ones.
    - Contract stickiness may be intended (e.g. firms commit not to change piece rate to avoid ratchet effect) or unintended (e.g. fairness norms arise around existing contracts).
  - There are complementarities between technological innovations (e.g. offset die) and organizational innovations (e.g. conditional contracts).
  - Workers need to expect to share in gains to adoption in order for adoption to be successful.

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