14.771 Development Economics: Microeconomic issues and Policy Models
Fall 2008

14.771: Technology Lecture 1

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Outline

- Technology Adoption (through the lens of agriculture)
  - Does it matter? Why doesn't everyone adopt? What's the big problem here?
  - Learning
  - Savings and other problems
- Other issues in technology
  - How learning from neighbors can get you the wrong answer
  - How technology can affect markets
  - Appropriate technology

What's the problem? Why doesn't everyone adopt?

- Duflo, Kremer and Robinson (2008)
- Setting:
  - Maize farming in Kenya
  - Technology is fertilizer ("top-dressing", which is fertilizer applied after plant has germinated and probability it will grow to fruition is high)
  - Farmer adds fertilizer 2 months after planting
  - "Return" is realized 7 months later, when farmer can consume extra maize the produced rather than buy it at the market price
- Design:
  - Randomized experiment where farmers are randomized into different levels of fertilizer use or control

Results

- Key result: potential for very high returns, but only if you get the amounts right

Table 1: Returns to Fertilizer

	Mean (1)	Median (2)	Std. Error (3)	Obs. (4)
Panel A. 1/4 Teaspoon Top Dressing Fertilizer				
Percentage Increase in Yield	28.1	8.9	6.8	112
Rate of Return Over the Season	4.8	-27.7	38.8	112
Annualized Rate of Return (at the Mean and Median)	8.4	-42.6		112
Panel B. 1/2 Teaspoon Top Dressing Fertilizer				
Percentage Increase in Yield	47.6	24.3	6.1	200
Rate of Return Over the Season	36.0	23.9	16.9	202
Annualized Rate of Return (at the Mean and Median)	69.5	44.4		202
Panel C. 1 Teaspoon Top Dressing Fertilizer				
Percentage Increase in Yield	63.1	30.6	8.2	273
Rate of Return Over the Season	-10.8	-16.9	8.4	274
Annualized Rate of Return (at the Mean and Median)	-17.8	-27.3		274
Panel D. Full Package Recommended by Ministry of Agriculture				
Percentage Increase in Yield	90.6	48.7	15.4	82
Rate of Return Over the Season	-38.9	-49.4	10.4	85
Annualized Rate of Return (at the Mean and Median)	-48.2	-59.7		85

Note: A/B/C vs. control were done in different seasons

Technology adoption

- Heterogeneity in returns suggests learning is important, not just about whether to adopt, but how to adopt
- Several ways to think about technology adoption:
- Learning
  - About (constant) returns to technology
  - About (constant) appropriate use of technology
  - About (idiosyncratic) appropriate use of technology
- Deciding whether to adopt
  - Risk aversion
  - Credit constraints
  - Time-consistent preferences

Learning: the empirical identification challenge

- General problem: in cross section, correlated shocks cannot be distinguished from learning
- Consider the simplest case:

$$y_{ig} = \alpha + \beta \overline{y}_g + u_g + \varepsilon_i$$

  where u is an unobserved common shock. Since u is unobserved, we cannot identify β.
- Some options for identification we will discuss:
  - Use panel data and exploit time structure (Foster and Rosenzweig)
  - Distinguish between learning group and information group so $\overline{y}_g$ and u_s refer to different groups (Conley and Udry)
  - Use experiments to shock one individual only so we know there are no common shocks (Duflo, Kremer, and Robinson)

Foster and Rosenzweig (1995)

- Overview:
- Model of agricultural technology adoption
- In the model, optimal use of technology is idiosyncratic, so farmers need to experiment to learn how to use the technology in a way appropriate for local conditions
- Farmers can learn both from their own experience and from the experience of their neighbors
- This predicts that farmers under-experiment relative to the social optimum, so adoption is too slow
- Test model using panel data from India

Model setup

- Optimal use of technology is

$$\widetilde{\theta}_{ijt} = \theta^* + u_{ijt}$$

where θ^* is mean (unknown) optimal use and u_{ijt} is iid error term with variance σ_u^2.

- Farmers have priors over θ^* that are $N\left(\theta_{j0}, \sigma^2_{\theta j0}\right)$.
- HYV yield for parcel i:

$$\eta_a + \eta_h - \eta_{ha}\frac{i}{A_j} - \left(\theta_{ijt} - \widetilde{\theta}_{ijt}\right)^2$$

where a is alternative, h hybrid, A_j is total number of plots, i is plot number

- Expected profits for a farmer are therefore

$$E\pi_{jt} = \left(\eta_h - \eta_{ha}\frac{H_j}{2A_j} - \sigma^2_{\theta jt} - \sigma^2_u\right) H_j + \eta_a A_j + \mu_j + \varepsilon_{pjt}$$

Learning

- Farmers update their priors about the optimal way to use the technology (θ) using Bayes' rule
- This implies that

$$\sigma^2_{\theta jt} = \frac{1}{\rho + \rho_0 S_{jt} + \rho_v \overline{S}_{-jt}}$$

where ρ's are "precisions" of information (inverse of variances):

$$\begin{aligned} \rho &= \frac{1}{\sigma^2_{\theta 0}} \\ \rho_0 &= \frac{1}{\sigma^2_u} \\ \rho_v &= \frac{n}{(\sigma^2_u + \sigma^2_k)} \end{aligned}$$

and where S_{jt} is own experience, n is number of neighbors, and $\overline{S}_{-jt}$ is average neighbor experience (you observe neighbor with more noise)

Technology Adoption

- Farmer's choice variable is H_{jt}, i.e., how many plots to plant HYVs in this year
- Farmer chooses H_{jt} to maximize:

$$V_{jt} = \max_{H_{jx}} E_t \sum_{x=t}^{T} \delta^{x-t} \pi_{jx}$$

or equivalently in Bellman form:

$$\begin{aligned} V_{jt} &= \max_{H_j} \left(\eta_h - \eta_{ha} \frac{H_j}{2A_j} - \frac{1}{\rho + \rho_0 S_{jt} + \rho_v \overline{S}_{-jt}} - \sigma_u^2 \right) H_j \\ &\quad + \eta_a A_j + \mu_j + \delta V_{jt+1} \end{aligned}$$

- Planting decisions therefore depend (positively) on past history of own and neighbors' planting, (positively) on expectations about own future planting, and (ambiguous, maybe negative) on expectations about neighbors' planting

Technology Adoption

- Taking derivatives with respect to H_j the first order condition is that:

$$\eta_h - \eta_{ha}\frac{H_j}{A_j} - \frac{1}{\rho + \rho_0 S_{jt} + \rho_v \overline{S}_{-jt}} - \sigma_u^2 = -\delta\frac{\partial V_{t+1}}{\partial S_{jt}}$$

- Note that at optimum interior solution, current period marginal benefit of H is negative – i.e., you do some extra experimentation to gain knowledge usable in the future

Restrictions/Implications

- Ratio of marginal impact of own and neighbors experience is a time-invariant constant since relative precision of additional information gained by each does not change over time – i.e,

$$\frac{\frac{\partial \pi_{jt}}{\partial S_{jt}}}{\frac{\partial \pi_{jt}}{\partial \overline{S}_{-jt}}} = \frac{\rho_0}{\rho_v}$$

- Value of additional own and neighbor's information diminish over time as long as HYV use is positive, and at the same rate, i.e.,

$$\frac{\frac{\partial(\pi_{jt+1}/H_{jt+1})}{\partial S_{jt+1}}}{\frac{\partial(\pi_{jt}/H_{jt})}{\partial S_{jt}}} = \frac{\frac{\partial(\pi_{jt+1}/H_{jt+1})}{\partial \overline{S}_{-jt+1}}}{\frac{\partial(\pi_{jt}/H_{jt})}{\partial \overline{S}_{-jt}}} = \frac{\left(\rho + \rho_0 S_{jt} + \rho_v \overline{S}_{-jt}\right)^2}{\left(\rho + \rho_0 S_{jt+1} + \rho_v \overline{S}_{-jt+1}\right)^2} < 1$$

- If no learning from neighbors $(\rho_v = 0)$, then neighbor's assets (A_{-j}) do not affect farmer's decisions
- Effect of neighbor's assets that predict HYV planting could be negative, although own effects of assets are positive

Estimation

- Recall profit function (augmented to include education, denoted E)

$$\pi_{jt} = \left(\eta_h - \eta_{ha}\frac{H_j}{2A_j} - \frac{1}{\rho + \rho_0 S_{jt} + \rho_v \overline{S}_{-jt}} - \sigma_u^2 + \eta_{he}E_j\right) H_j + \eta_a A_j + \mu_j + \varepsilon_{pjt}$$

- Taking linear approximation yields

$$\pi_{jt} = \left(\eta_h' + \beta_{0t}S_{jt} + \beta_{vt}\overline{S}_{-jt} + \eta_{he}E_j\right) H_j + \eta_a' A_j + \mu_j + \varepsilon_{pjt}$$

where

$$\beta_{ot} = \frac{\rho_o}{\rho + (\rho_o + \rho_v) S_t}, \beta_{vt} = \frac{\rho_v}{\rho + (\rho_o + \rho_v) S_t}$$

where S_t is some average level of S around which we take approximations.

- How does this differ from what you might have written down from reduced form perspective?
  - Main effects of S_{jt} and S_{-jt}? Which makes more sense?

Estimation notes

- Take first differences to remove fixed effect, and retain both current and lagged S variables. This yields:

$$\begin{aligned}\Delta\pi_{jt} &= \eta_h'\Delta H_j + \beta_{0t+1}S_{jt+1}H_{jt+1} + \beta_{vt+1}\overline{S}_{-jt+1}H_{jt+1} \\ &\quad -\beta_{0t}S_{jt}H_{jt} - \beta_v\overline{S}_{-jt}H_{jt} - \eta_{he}E_j\Delta H_{jt} + \eta_a'\Delta A_{jt} + \Delta\varepsilon_{pjt}\end{aligned}$$

- By allowing coefficients β_0 and β_v to differ over time, they can test whether learning changes over time
- Estimate using instrumental variables.
  - What are the concerns?
    - Weather, pests: if some component of profitability is known ex-ante and affects HYV adoption decision, you could get bias.
    - Lagged profit shocks can affect HYV adoption through learning
  - Instruments are inheritance of assets and lags of ΔA and H (i.e., use levels of assets and lags to instrument for changes)
    - Are these good instruments?
- Adoption (ΔH_{jt}) regressions are similar

Results-Specification Check

- Check: village experience with HYV should not affect profitability of non-HYV farmers. Not true in cross-section but true in panel.

Cross-Sectional and Panel Estimates of Profit Function for Farmers not Using HYVs

	OLS (N = 1,536)	*Fixed effects (N = 1,277)*	*Instrumental variables fixed effects (N = 1,277)*	
	(1)	*(2)*	*(3)*	*(4)*
Village experience	.137 (1.84)	-.187 (.654)	-.246 (.804)	-.240 (.784)
Initial period village experience				.166 (.514)
Equipment	.085 (1.29)	.597 (2.11)	2.94 (2.90)	2.90 (2.85)
Irrigation assets	.162 (7.68)	.050 (.691)	.425 (2.00)	.440 (2.06)
Animals	.657 (17.9)	-.377 (2.30)	-1.74 (4.16)	-1.76 (4.20)
Primary schooling (x 10^2)	1.77 (2.01)	--	--	--
Irrigated land	.018 (7.01)	--	--	--
Unirrigated land	.032 (9.34)	--	--	--
House	.026 (3.41)	--	--	--

Note: All variables are treated as endogenous for instrumental variables, fixed-effect estimates. Instruments include inherited assets, lagged asset flows, lagged profits, lagged village HYV use, and weighted averages of these variables by village. Absolute asymptotic t-ratios derived from Huber standard errors are in parentheses.

Figure by MIT OpenCourseWare.

Results-Profits

- Own and neighbor experience matters (but own matters much more)_ , experience declines over time
- Ratio of decline over time similar for own and neighbor information

Determinants of Farm Profits from HYV Use (N = 450)

HYV effects	*Linear approximation*			*Structural estimates: Nonlinear instrumental variables fixed effects*
	Instrumental variables fixed effects		*Constrained instrumental variables fixed effects*	
	(1)	*(2)*	*(3)*	*(4)*
β_α (x 10^5)	.170 (2.13)	.293 (2.54)	.187 (1.88)	--
$\beta_{\alpha-1}$ (x 10^5)	.754 (2.47)	1.05 (2.18)	--	--
β_α (x 10^5)	--	.349 (2.16)	.341 (2.63)	--
$\beta_{\alpha-1}$ (x 10^5)	--	1.93 (2.64)	--	--
λ_μ	--	--	4.33 (10.6)	--

Figure by MIT OpenCourseWare.

Results-Adoption

- Neighbors assets negatively affect your adoption – which they interpret as evidence of free riding on experimentation

Farm equipment: neighbor (x 10^{-4})	--	-.0878 (.34)	-.0194 (.06)
Farm animals: neighbor (x 10^{-4})	--	-.995 (2.08)	-.948 (1.85)
Irrigation assets: neighbor (x 10^{-4})	--	-2.12 (3.58)	-2.07 (3.38)
Trend (x 10^{-2})	3.85 (2.54)	4.04 (2.65)	4.07 (2.53)

Figure by MIT OpenCourseWare.

Discussion

- In general, it is very hard to separate peer effects (learning) from common shocks
- In this paper, they do this in two ways:
  - Looking at lag values
  - Instrumenting using levels (in a difference equation) and lags
  - Are these convincing?
- Does learning from others speed up or slow down technology adoption?
  - Two effects: benefits from learning, but free riding on neighbors
  - On net simulations imply profits improve with spillovers, but time to adoption is slower

Conley and Udry (2005)

- Setting:
  - Pineapple growers in Ghana
  - Learning whether and how much fertilizer to use from the experience of neighbors
- Similar idea to F&R: technology is local, so you need to see how it works locally to use it correctly

Conley and Udry vs. Foster and Rosenzweig

- Data improvements
  - Data on who you discuss farming with, so we can construct the people who you learn from better than village level aggregates in F&R
  - Moreover, network information allows them to distinguish between spacial correlation (common shocks) and who you learn from
- Sharper empirics
  - In F&R, the idea is you learn about optimal input level from neighbor's experience but this is unobserved
  - In C&Y, they observe input choices of you and neighbors. They then test whether you change your inputs in response to new information about productivity of neighbors.
  - This is the same prediction as the F&R model; C&Y they just have the data to look at it directly

Empirical setup

- Two categories: use fertilizer $(x > 0)$ or not $(x = 0)$
- For each level of x, calculate expectations of profits based on past realizations of profits for neighbors. Denote this $\widehat{E}_{it}\left[\pi_{k,t+1}\left(x_{kt}, w_{kt}\right)\right]$ where w measures growing conditions and k is a similar set of plots.
- "Good news" if

$$d_{i,k,t} = \pi_{k,t+1}\left(x_{kt}, w_{kt}\right) > \widehat{E}_{it}\left[\pi_{k,t+1}\left(x_{kt}, w_{kt}\right)\right]$$

- Index of good news defined as number of neighbor's plants with same input type for which good news was reported, expressed as share of total neighbor's plants ever seen

$$G_{i,t_1}\left(x = x_{i,t_0}\right) = \frac{1}{TotalPlants_{i,t_t}} \sum_{k \in N_i} 1\left\{x_{i,t_0} = x_{k,t_0}\right\} d_{i,k,t_0} Plants_{k,t_0}$$

- Define good news for alternative input choices and bad news for same and alternate input choice analogously

Empirical setup

- Similarly, define
  - M as where (relative to x_0) the good news is. You should therefore update in the direction of M.
  - Γ as difference between what you and your geographic neighbors do
    - Not quite analogous – we would probably have liked it to be exactly the same to really tease out geography vs. information sets, but so be it
- Probability of change regression

$$\Pr\{\Delta x_{i,t} \neq 0\} = \Lambda \left[\begin{array}{c} \alpha_1 G_{it}(x = x_{i,t-1}) + \alpha_2 G_{it}(x \neq x_{i,t-1}) \\ +\alpha_4 B_{it}(x = x_{i,t-1}) + \alpha_4 B_{it}(x \neq x_{i,t-1}) \\ +\alpha_5 Geog + z'_{I,T}\alpha_6 \end{array} \right]$$

- Directional change regression

$$\Delta x_{i,t} = \beta_1 M_{i,t} + \beta_2 \Gamma_{i,t} + z'_{i,t}\beta_3 + \varepsilon$$

Results

Table 4: Predicting the Change in Input Use

Dependent Variable: Indicator of a Change in Per Plant Fertilizer Use

	A	B
Good News at Lagged Fertilizer Use	-0.13 [1.19]	0.05 [1.16]
Good News at Alternative Fertilizer Use	0.18 [0.97]	0.37 [1.02]
Bad News at Lagged Fertilizer Use	12.32 [3.72]	14.41 [4.63]
Bad News at Alternative Fertilizer Use	-2.98 [1.91]	-4.22 [2.07]
Average Absolute Deviation from Geographic Neighbors' Fertilizer Use	0.49 [0.13]	0.49 [0.14]

Results

Table 5: Predicting Innovations in Input Use, Differential Effects by Source of Information

Dependent Variable: Innovation in Per Plant Fertilizer Use

	A	B	C	D	E	F
Index of Inputs on Successful Experiments (M)	0.99					
	[.16]					
M * Inexperienced Farmer		1.09				
		[0.22]				
M * Experienced Farmer		0.10				
		[0.32]				
Inexperienced Farmer		4.01	4.20	4.22	4.19	4.12
		[2.62]	[2.66]	[2.65]	[2.65]	[2.77]
Index of Experiments by Inexperienced Farmers			-0.13			
			[0.37]			
Index of Experiments by Experienced Farmers			1.02			
			[0.17]			
Index of Exper. by Farmers with Same Wealth				1.03		
				[0.18]		
Index of Exper. by Farmers with Different Wealth				-0.41		
				[0.32]		
Index of Experiments on Big Farms					1.10	
					[0.14]	
Index of Experiments on Small Farms					0.89	
					[0.18]	
Index of Exper. by Farmers with Same Soil						1.04
						[0.16]
Index of Exper. by Farmers with Different Soil						0.91
						[0.19]

Discussion

- These results provide more direct confirmation for the Foster & Rosenzweig story:
  - People adjust their fertilizer use based on neighbor's experience, particularly bad news from n
  - Effects particularly strong for inexperienced farmers.
  - People also pay attention more to farmers with similar wealth and more experience

Duflo, Kremer and Robinson (2006)

- Same experiments on fertilizer use in Kenya discussed at beginning of lecture
- Several treatments to investigate learning:
  - Shock farmers with information and test inputs (fertilizer) in period 1 and look at impact over time ("demonstration plot")
  - Shock farmers with test inputs only (fertilizer) in period 1 and look at impact over time ("starter kit")
  - Ask demonstration plot farmers (in treatment and control) to name people with whom they discuss agriculture. Then randomly invite one of those people to attend discussion.
- Key dependent variable: did you adopting fertilizer in subsequent years

Results

- Farmers in demonstration plot continue to use over time, but effect is only 10-17 percentage points. Suggests other factors may matter

Table 2: Adoption for Farmers Participating in Demonstration Plot

	1 season later		*2 seasons later*		*3 seasons later*	
Panel A. All Farmers	(1)	(2)	(3)	(4)	(5)	(6)
	fertilizer	*any treatment*	*fertilizer*	*any treatment*	*fertilizer*	*any trea*
Demonstration Plot Farmer	0.107	0.107	0.089	0.061	0.101	0.0
	(0.039)***	(0.042)**	(0.044)**	(0.046)	(0.050)**	(0.05
Observations	580	577	523	521	450	447
Panel B. Only Farmers with at least 3 seasons of Adoption Data						
	(1)	(2)	(3)	(4)	(5)	(6)
	fertilizer	*any treatment*	*fertilizer*	*any treatment*	*fertilizer*	*any trea*
Demonstration Plot Farmer	0.169	0.172	0.113	0.065	0.112	0.07
	(0.050)***	(0.056)***	(0.054)**	(0.059)	(0.054)**	(0.06
Observations	371	364	371	364	371	364

Standard errors in parentheses
* significant at 10%; ** significant at 5%; *** significant at 1%
Regressions control for school.

Courtesy of Esther Duflo, Michael Kremer, and Jonathan Robinson. Used with permission.

Results

- Starter kits half as effective and effect diminishes over time – suggests external information is important

Table 3: Adoption for Farmers Offered Starter Kits

	1 season later		2 seasons later	
	(1)	(2)	(3)	(4)
	fertilizer	*any treatment*	*fertilizer*	*any treatmer*
Starter Kit Farmer	0.051	0.063	0.019	0.021
	(0.029)*	(0.029)**	(0.029)	(0.029)
Observations	1045	1042	1060	1059

Standard errors in parentheses
* significant at 10%; ** significant at 5%; *** significant at 1%
Regressions control for school.

Results

- Those invited to discuss results have similar effects as those who had experiment on own plot, although diminishes more rapidly
  - Maybe because without agricultural extension, they can't adapt fertilizer use properly to their own plots? We don't know.
- No spillovers on other neighbors.
  - Some evidence people in this area don't discuss farming much - only 46% of farmers can state what neighbors planted

Table 4: Adoption for Agricultural Contacts

	1 season later		*2 seasons later*		*3 seasons later*	
Panel A. OLS	(1)	(2)	(3)	(4)	(5)	(6)
	fertilizer	*any treatment*	*fertilizer*	*any treatment*	*fertilizer*	*any treatment*
Invited Agricultural Contact	0.093	0.103	0.031	0.054	-0.014	-0.022
	(0.055)*	(0.059)*	(0.061)	(0.065)	(0.058)	(0.064)
Uninvited Agricultural Contact	0.002	-0.042	-0.015	-0.004	-0.015	-0.013
	(0.035)	(0.038)	(0.038)	(0.041)	(0.037)	(0.040)
Observations	708	706	580	580	557	556
B. Panel B: 2SLS	(1)	(2)	(3)	(4)	(5)	(6)
	fertilizer	*any treatment*	*fertilizer*	*any treatment*	*fertilizer*	*any treatment*
Came to Treatment (instrumented	0.212	0.236	0.072	0.126	-0.03	-0.049
with Invited Agricultural Contact)	(0.127)*	(0.138)*	(0.142)	(0.151)	(0.129)	(0.141)
Uninvited Agricultural Contact	-0.002	-0.047	-0.017	-0.007	-0.014	-0.012
	(0.037)	(0.040)	(0.039)	(0.042)	(0.037)	(0.041)
Observations	708	706	580	580	557	556

Standard errors in parentheses

* significant at 10%; ** significant at 5%; *** significant at 1%

Concluding thoughts

- In general the results suggest that an important part of technology adoption is learning how to use it, not just whether to use it. There are therefore important returns to experience and spillovers
- Spillovers probably somewhat context dependent: depends how much you talk to neighbors
- Examples from agriculture, but this may be more general
  - Thought experiment: think about moving from using Fortran to Stata.
  - May be some negative returns up front since you don't know how to use Stata and you need to figure it out; your first attempts may not work
  - Easier to learn how to use it if you can ask your friends how to use it, get examples of their code, etc.
- Results from Kenya experiments suggest that there may be important other facts as well: more next time on this