Money Matters:
The role of yields and profits in agricultural technology adoption

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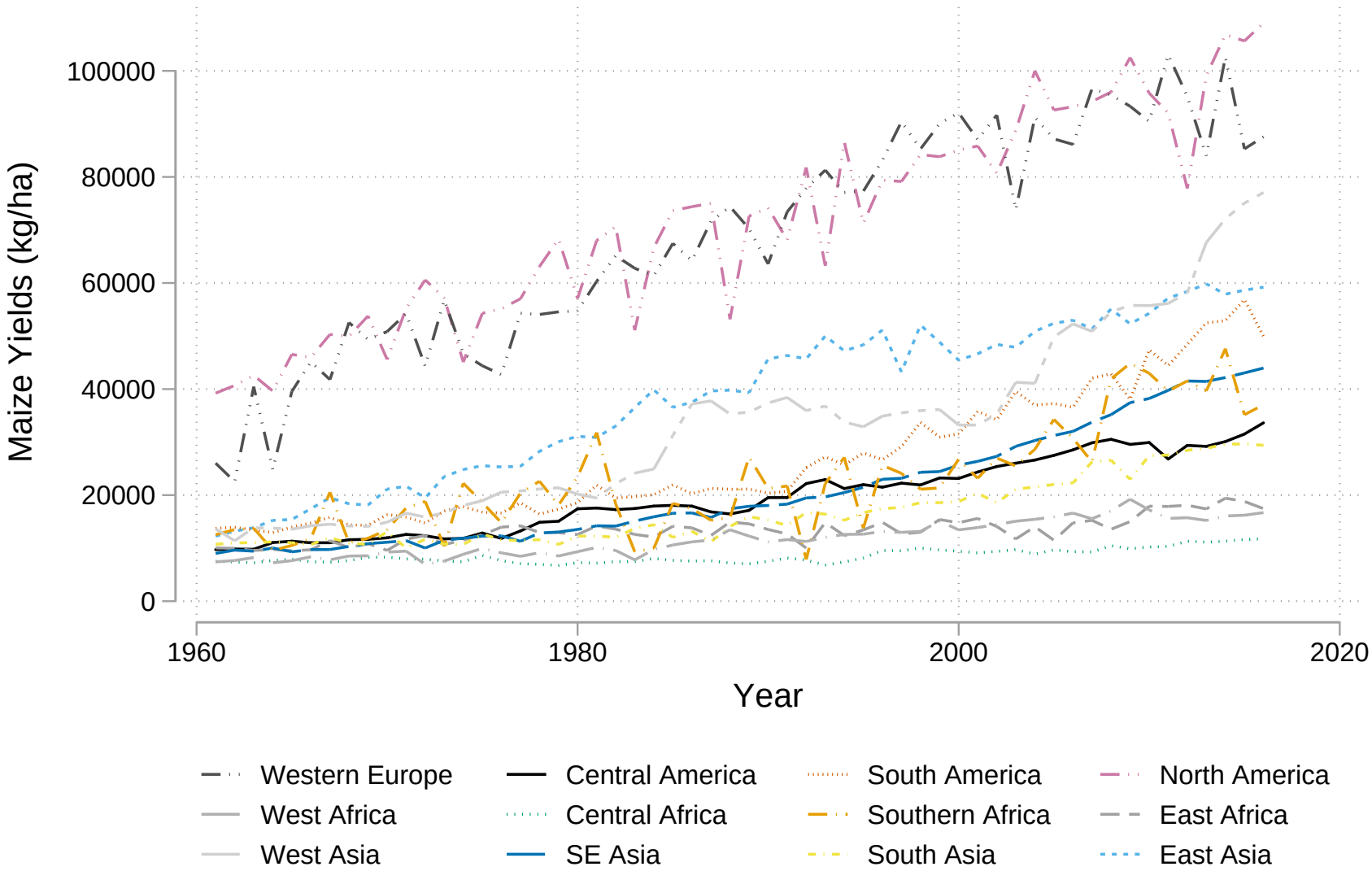
The Technology Adoption Puzzle



Constraints to Technology Adoption

- Why do adoption rates of many proven technologies remain low among smallholder farmers in developing countries?
  - Credit markets (Croppenstedt et al., 2003)
  - Property rights (Place and Swallow, 2000)
  - Learning externalities (Foster and Rosenzweig, 1995)
  - Social networks (Maertens and Barrett, 2013)
  - Lack of commitment (Kremer et al., 2011)

An Empirical Puzzle?

- Suri (2011) proposed a "new" explanation: uncontrolled-for heterogeneity
  - Average returns to adoption are high
  - But returns to individual farmers may be heterogeneous
  - Heterogeneity is due to unobservable comparative advantage
  - Standard fixed effects only control for absolute advantage
  - Failing to control for unobserved comparative advantage biases results
- She shows this is the case for adoption of hybrid maize in Kenya
  - Average returns are positive and significant
  - Farmers with the highest returns also have the highest costs of adoption and therefore do not adopt

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Our Own Empirical Puzzle

1. What explains adoption of improved chickpea in Ethiopia?
   - Adoption has been very high $\approx 80\%$
   - Standard panel data methods $\rightarrow$ technology does not increase yields
2. Is this due to failure to control for unobserved heterogeneity?
   - Conduct an extension test of Suri (2011)
   - Find no evidence of a significant role for unobserved heterogeneity
3. What then explains the high adoption rates?
   - Many studies impute a value for production using market prices
   - But many households never actually receive this price
   - We explore the returns to adoption in terms of costs of production and profits from sale of agricultural goods in the market

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Improved Chickpea

- Traditional variety: Desi, small brown seeds
- Recently introduced improved variety: Kabuli, large cream colored seeds
- From 2008-14 Kabuli adoption increased from 30% $\rightarrow$ 80%
- Ethiopia; world's 7^{th} largest producer of chickpea

Sources of Data

- Data collected in 2007, 2010, 2014
- Shewa region in central Ethiopia
- 678 households from 26 villages
- Use balance panel of 600 households
  - Measure yields as kg/ha
  - Measure costs as USD/ha using USD PPP with 2005 as base
  - Measure profits as USD/ha using net revenue from sale of agricultural goods in the market
- Use CHIRPS rainfall data

History of Adoption

	Transition of adoption			Fraction of sample (%)
	2007	2010	2014	($N = 600$)
Always adopter	Y	Y	Y	24.50
Early adopter	N	Y	Y	30.67
Late adopter	N	N	Y	20.00
Mixed adopter	Y	N	Y	4.00
Mixed dis-adopter	N	Y	N	6.33
Late dis-adopter	Y	Y	N	1.50
Early dis-adopter	Y	N	N	1.17
Never adopter	N	N	N	11.83

Basic DGP

- Focus on three-period model without covariates
- Assume the data generating process is:

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

- h_{it} indicates adoption
- β average returns to adoption
- ϕ measures significance of CA term
- θ_i comparative advantage
- ζ_i absolute advantage (household FE)
- ε_{it} idiosyncratic error

History of Adoption

- The key to Suri's (2011) CRC model is projecting the comparative advantage term on the history of the household's adoption behavior
- Similar to what Chamberlain (1984) does in his CRE model

$$\theta_i = \lambda_0+\lambda_1 h_{i1}+\lambda_2 h_{i2}+\lambda_3 h_{i3}+\lambda_4 h_{i1} h_{i2}+\lambda_5 h_{i1} h_{i3}+\lambda_6 h_{i2} h_{i3}+\lambda_7 h_{i1} h_{i2} h_{i3}+\nu_i$$

- By including $h_{it}\ \forall t$ and $h_{it} hiq\ \forall t, q$ s.t. $t \neq q$, we ensure that ν_i is uncorrelated with the adoption decision

Implementation

- Though Suri (2011) has been cited +400 times, only one other paper actually use her CRC method
  - Nyshadham, A. 2014. "Learning about Comparative Advantage in Entrepreneurship: Evidence from Thailand." *Mimeo*, Yale.
- Might be because the code initially built in Gauss just estimated Suri's 2-year model
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OLS and FE Estimation of Yield Function

	Ln chickpea yield (kg/ha)			
	OLS	OLS	FE	FE
Improved chickpea	0.258***	0.127*	0.054	0.076
	(0.072)	(0.070)	(0.089)	(0.088)
Covariates	No	Yes	No	Yes
Year Controls	Yes	Yes	Yes	Yes
Household Controls	No	Yes	No	Yes
District Controls	Yes	Yes	No	No
Household FE	No	No	Yes	Yes
Observations	1,408	1,408	1,408	1,408
R^2	0.043	0.163	0.006	0.058

CRE and CRC Estimation of Yield Function

	Ln chickpea yield (kg/ha)			
	CRE	CRE	CRC	CRC
Improved chickpea	−0.041	0.057	−0.239	0.012
	(0.074)	(0.073)	(0.628)	(0.108)
Comparative advantage			6.647	2.271
			(18.86)	(4.109)
Covariates	No	Yes	No	Yes
Observations	1,011	1,011	1,011	1,011
χ^2	1,472	1,651***	4,341***	4,504***

OLS and FE Estimation of Cost Function

	Ln production cost (USD/ha)			
	OLS	OLS	FE	FE
Improved chickpea	−0.017	−0.079***	0.054*	−0.045**
	(0.026)	(0.014)	(0.030)	(0.018)
Covariates	No	Yes	No	Yes
Year Controls	Yes	Yes	Yes	Yes
Household Controls	No	Yes	No	Yes
District Controls	Yes	Yes	No	No
Household FE	No	No	Yes	Yes
Observations	1,800	1,800	1,800	1,800
R^2	0.136	0.769	0.004	0.754

CRE and CRC Estimation of Cost Function

	Ln production cost (USD/ha)			
	CRE	CRE	CRC	CRC
Improved chickpea	0.054	−0.044**	0.042	−0.047*
	(0.037)	(0.017)	(0.040)	(0.018)
Comparative advantage			−0.241	0.909
			(0.265)	(1.667)
Covariates	No	Yes	No	Yes
Observations	1,800	1,800	1,800	1,800
χ^2	3,237***	1,069	6,517***	3,112***

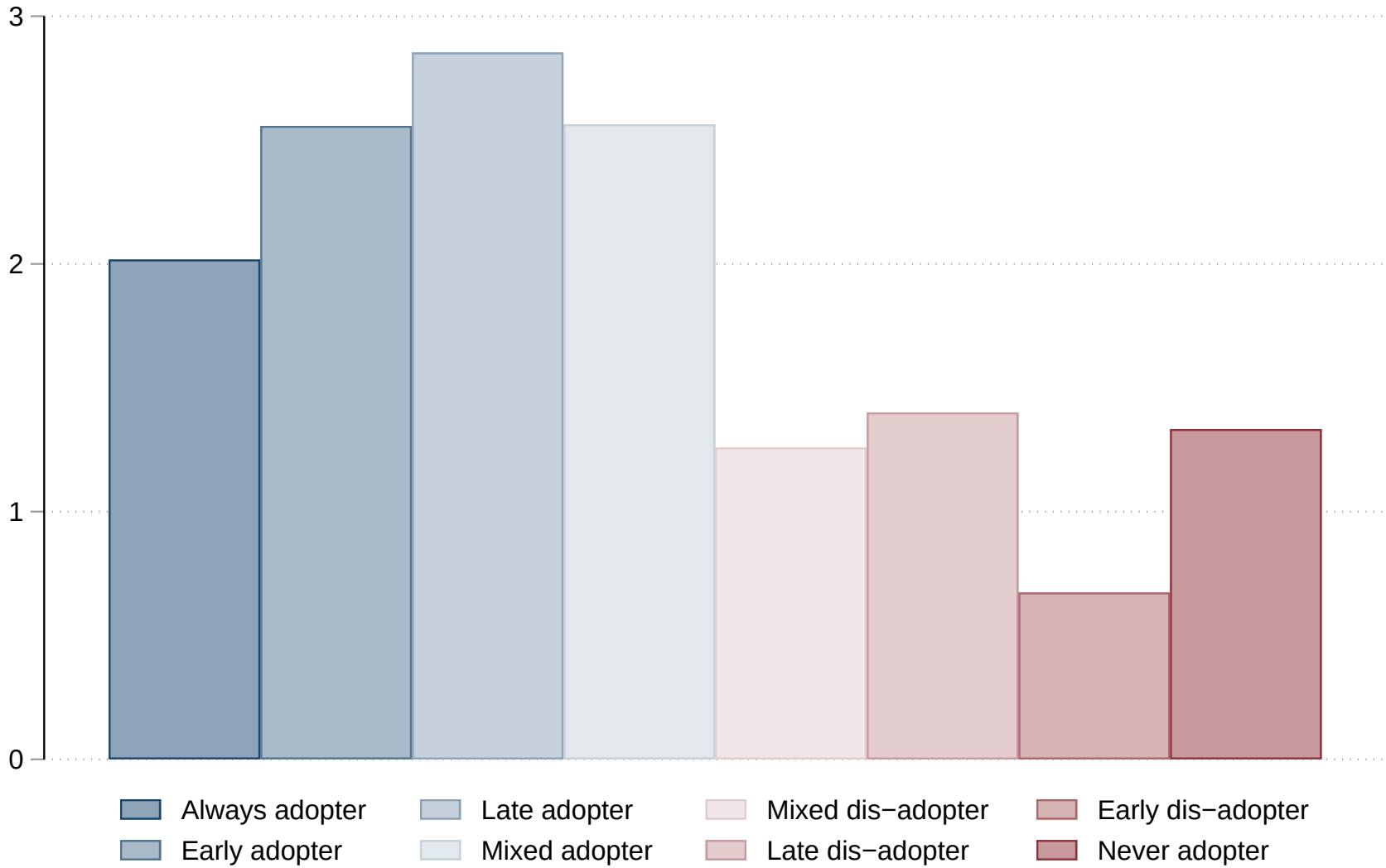
OLS and FE Estimation of Profit Function

	Ln on-farm profit (USD/ha)			
	OLS	OLS	FE	FE
Improved chickpea	2.849***	2.814***	2.523***	2.379***
	(0.308)	(0.311)	(0.390)	(0.399)
Covariates	No	Yes	No	Yes
Year Controls	Yes	Yes	Yes	Yes
Household Controls	No	Yes	No	Yes
District Controls	Yes	Yes	No	No
Household FE	No	No	Yes	Yes
Observations	1,800	1,800	1,800	1,800
R^2	0.178	0.246	0.135	0.129

CRE and CRC Estimation of Profit Function

	Ln on-farm profit (USD/ha)			
	CRE	CRE	CRC	CRC
Improved chickpea	2.487***	2.330***	2.269***	2.360***
	(0.407)	(0.407)	(0.472)	(0.505)
Comparative advantage			1.202	4.325
			(1.335)	(9.198)
Covariates	No	Yes	No	Yes
Observations	1,800	1,800	1,800	1,800
χ^2	11,513***	2,952***	15,204***	7,403***

Distribution of Returns for Profits



In Brief

What is going on here?

- High levels of adoption
- No gains in terms of yields
- Some reduction in costs
- Large gains in terms of profits
- No significant heterogeneity in returns across all three measures

Potential Confounders

- Measurement error in valuing on-farm family labor or home consumption
  - Measure family labor in days
  - Value family labor based on gov't rural wage data or on estimated shadow wage
  - Measure home consumption at a variety of market prices
- Bias due to endogeneity in measured inputs
  - Stata CRC package can accommodate an additional endogenous variable
  - Control for potential endogeneity in allocation of family labor
  - Control for potential endogeneity in application of chemical pesticide/herbicide
- None of these fundamentally change our results

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Potential Mechanisms

- If it is not yield gains, nor unobserved heterogeneity in returns, nor bias from confounding factors, what is driving the large gains in profitability?
  - Change in cropping patterns that help explain cost savings
  - Increased marketability of crop production that helps explain profit gains

Comparing Always Adopters to Future Dis-adopters

	2007			2014		
	Always adopter	Future dis-adopter	MW-test	Always adopter	Future dis-adopter	MW-test
Herfindahl Index	0.309	0.341		0.302	0.375	**
	(0.085)	(0.134)		(0.082)	(0.149)	
Shannon Index	-0.300	-0.329		-0.294	-0.361	**
	(0.078)	(0.118)		(0.076)	(0.129)	
Cultivated area allocated to chickpea (%)	27.14	29.02		25.81	21.32	
	(14.07)	(20.34)		(10.78)	(8.46)	
Agricultural sales income (USD)	4,874	4,350		2,098	918.6	***
	(3,915)	(4,493)		(2,336)	(1,064)	
Share of chickpea production sold (%)	63.61	59.91		48.65	22.22	***
	(29.37)	(24.51)		(24.63)	(9.94)	
Chickpea share of sales income (%)	38.97	31.82		31.94	25.04	
	(23.31)	(31.18)		(25.42)	(33.72)	
Observations	147	16		147	16	

Comparing Never Adopters to Future Adopters

	2007			2014		
	Never adopter	Future adopter	MW-test	Never adopter	Future adopter	MW-test
Herfindahl Index	0.393	0.409		0.409	0.331	***
	(0.126)	(0.141)		(0.151)	(0.093)	
Shannon Index	-0.377	-0.390		-0.391	-0.322	***
	(0.112)	(0.124)		(0.131)	(0.086)	
Cultivated area allocated to chickpea (%)	20.25	18.88		17.47	26.51	***
	(14.06)	(10.09)		(9.79)	(12.21)	
Agricultural sales income (USD)	2,227	2,727	*	683.0	1,521	***
	(1,724)	(2,212)		(875.7)	(1,253)	
Share of chickpea production sold (%)	59.23	58.90		29.56	57.77	***
	(14.42)	(23.17)		(18.67)	(25.30)	
Chickpea share of sales income (%)	24.42	22.67		18.25	39.24	***
	(23.00)	(18.36)		(29.74)	(27.09)	
Observations	71	304		71	304	

Conclusions

1. What explains adoption of improved chickpea in Ethiopia?
   - Not yield gains, which are not significant across a large number of regressions
2. Is this result due to failure to control for unobserved heterogeneity?
   - No evidence of significant heterogeneity in returns
3. What then explains the high adoption rates of a technology that does not significantly increase yields?
   - Adoption appears to be due to small cost savings and large gains in profit
   - Potentially due to reallocation from high cost to low cost crops
   - Potentially due to increased marketing of improved chickpea

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Implications

- What then explains these "adoption puzzles"?
  - Maybe the focus on physical gains to new technology is misguided
- Money/markets matters
  - Beyond a certain point, households won't care about physical gains unless they can store or sell the surplus
  - Most adoption studies value crop production at market prices
  - But if markets are imperfect, this may be overvaluing physical gains to new technologies
  - The empirical puzzle may disappear once we measure returns in economic terms

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