Technology Adoption with Uncertain Profits: The Case of Fibre Boats in South India

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Motivation

Widespread empirical evidence that profitable new technologies fail to be adopted in low income environments

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Existing explanations:

- Positive externalities from learning about how to use the technology fail to be internalized (Foster and Rosenzweig, 1995)
- Aversion to crop-specific yield risk (Binswanger et al. 1980)
- Systematic under-estimation of the benefits of the new technology (Besley and Case, 1994)
- Credit constraints when technology is costly and individuals lack access to financial markets (Feder and et al., 1985)

Policy concerns about failure to adopt profitable new agricultural technologies

- Efficiency loss in food production, food security concerns in the presence of growing populations
- Stagnation of rural incomes
  $\rightarrow$ Rural-urban gap widens
- Poor rural households typically most affected
  $\rightarrow$ Rural inequality sharpens

Contribution of this Paper

For technology adoption, two additional channels potentially hindering technology adoption are identified:

- Individual-specific uncertainty about technology's benefits
- Credit constraint - even in the presence of a well-functioning financial market - due to non-exclusive credit contracts

Empirical Identification

Data with accurate measures of

1. Initial expectations about individual ability (how successfully the technology *is expected to be* operated)
2. Realization of individual ability (how successfully the technology *is* operated)

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Existing studies, in contrast, rely solely on ex post observed adoption decisions

Empirical Application

Switch form traditional wooden kattumarams to (more costly) fibre-reinforced plastic (FRP) boats in a village on the coast of southern Tamil Nadu, India, between 2001 and 2006

Outline of the Talk

- Introduction
- Empirical Setting
- Theoretical Framework
- Data
- Empirical Analysis
- Concluding Remarks

Empirical Setting

- Small-scale fishing with beach-landing crafts provides subsistence for a large proportion of fisherfolks on South India's coasts


PAKISTAN
HIMACHAL PRADESH
Shimla
Chandigarh
PUNJAB
UTTARANCHAL
Dehradun
DELHI
HARYANA
CHINA (TIBET)
ARUNAC
NEPAL
SIKKIM
Gangtok
BHUTAN
UTTAR PRADESH
Lucknow
RAJASTHAN
Jaipur
Patna
BIHAR
Shillong
MEGHALAYA
Agartala
TRIPURA
GUJARAT
Gandhinagar
Bhopal
MADHYA PRADESH
Ranchi
JHARKHAND
WEST BENGAL
Calcutta
CHHATTISGARH
Raipur
ORISSA
Bhubaneshwar
BANGLADESH
DIU
DAMAN
DADAR & NAGAR HAVELI
MAHARASHTRA
Mumbai (Bombay)
ARABIAN SEA
Hyderabad
DHRA PRADESH
YANAM (Pondicherry)
BAY OF BENGAL
Panaji
GOA
KARNATAKA
Bangalore
Chennai (Madras)
PONDICHERRY (Puduchchery)
KARAIKAL (Pondicherry)
LAKSHADWEEP
MAHE (Pondicherry)
TAMILNADU
KERALA
ANDAMAN & NICOBA
Thiruvananthapuram

Empirical Setting

- Small-scale fishing with beach-landing crafts provides subsistence for a large proportion of fisherfolks on South India's coasts
- Boats must have beach-landing capability, which limits size of raft
- Since mid 1990's, traditional rafts (kattumarams) have been replaced fibre-reinforced plastic boats (FRPs)

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- Since 1980's, 8-9 horse power outboard engines have become the dominant mode of propulsion for both kattumarams and FRPs
- FRP fishing yields roughly twice as much as kattumaram fishing with comparable labor inputs

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- FRP fishing yields roughly twice as much as kattumaram fishing with comparable labor inputs
- Cost of FRP four times the cost of kattumaram Rs. 60,000-80,000 vs. Rs. 15,000 to 20,000

Financing of FRPs

In the study village with 69 boat-owning households,
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The Credit cum Marketing Contract

- Auctioneer gives initial loan of D_0 for purchase of equipment
- Fisherman has to market all daily fish catches through the auctioneer
- Each day, auctioneer sells fisherman's catches to a group of traders
- Auctioneer keeps a share γ (7%) of sales revenue as commission and a share μ (10%) as debt reduction
- Remaining 83% of sales revenue are paid to fisherman later on the same day

Financing of FRPs

In the study village with 69 boat-owning households,
all 61 FRPs are financed by one of 14 fish auctioneers

Debt Renegotiation

- Fisherman can ask his auctioneer for additional loans, which are added to his concurrent debt level
- Fisherman can switch to another auctioneer if the latter is willing to advance more debt than his current auctioneer
  $\rightarrow$Borrower cannot commit to lender

Dynamics of the debt contract

		Fisherman produces output y_1		Fisherman produces output y_2		
Lender/trader advances D_0 to fisherman		Lender/trader keeps $(\gamma+\mu)y_1$		Lender/trader keeps $(\gamma+\mu)\, y_2$		
Fisherman owes D_0		Fisherman owes $D_0 - \mu y_1$		Fisherman owes $D_1 - \mu\, y_2$		
Fisherman adopts new technology		Fisherman may be granted additional loan, $D_1 \geq D_0 - \mu y_1$, and may switch lenders		Fisherman may be granted additional loan, $D_2 \geq D_1 - \mu y_2$, and may switch lenders		

Implication

- Additional debt is costless for fisherman
- Fisherman has incentive to ask for as much additional debt as he is granted at any date

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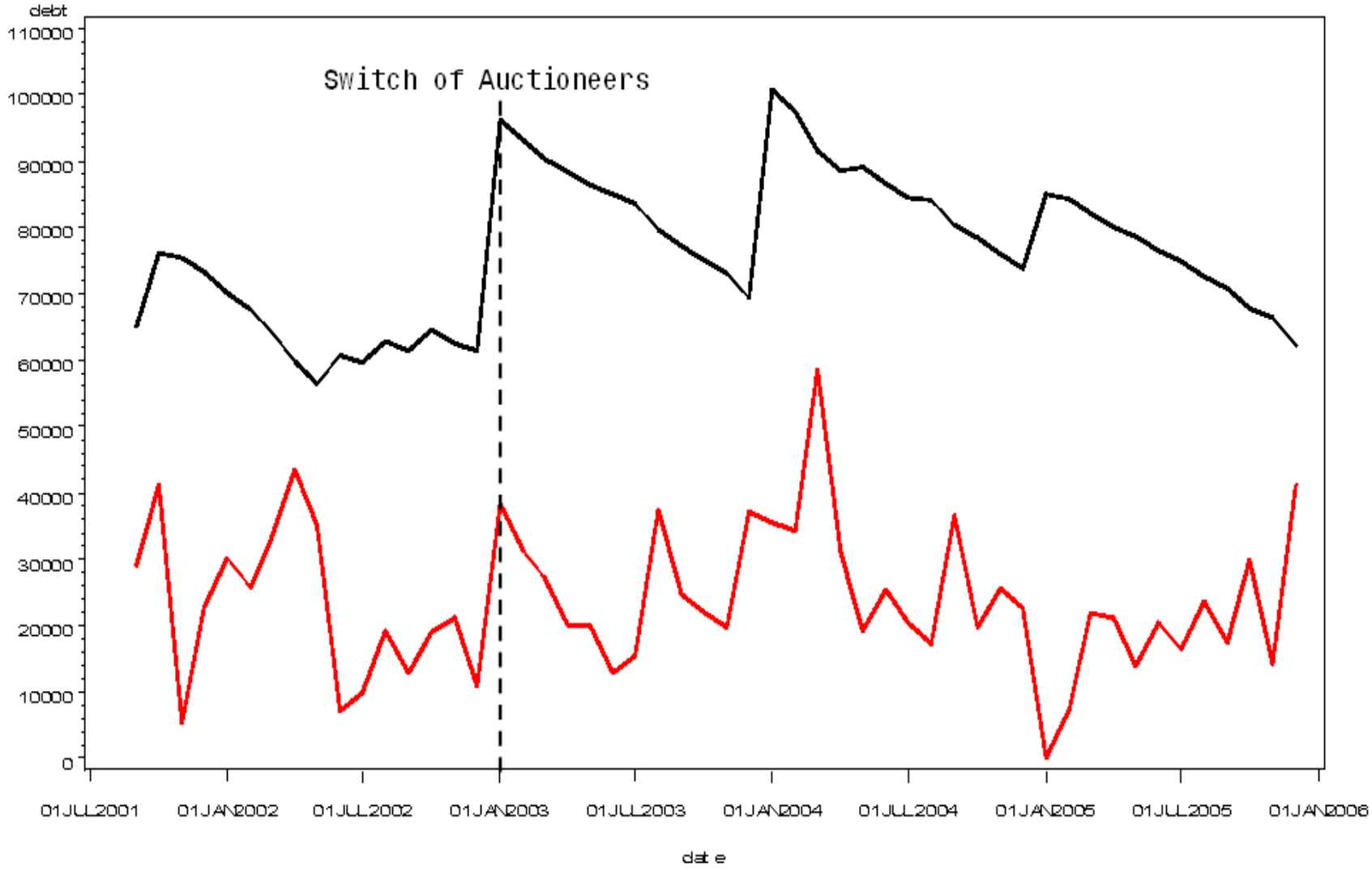
- Fisherman has incentive to ask for as much additional debt as he is granted at any date
  (No fisherman in our sample stated an intention to reduce his debt to zero and thus escape the credit cum marketing contract)

Debt (black) and Monthly Sales (red) of Fisherman Arun



Approach of this Paper

With

- competition among auctioneers
- costlessness of debt for fisherman,

a fisherman's debt level at any date reflects expectations about fisherman's future earning potential because auctioneer's income proportional to fisherman's performance

Approach of this Paper

Lending and sales data can be used to identify

1. Aggregate profitability uncertainty:
   Common value of the new technology unknown
2. Individual-specific profitability uncertainty:
   Technology has a different, unknown value for each individual
3. Credit constraint arising from non-exclusivity of debt contract

Theoretical Framework

Overview

Two models illustrating lending and sales dynamics under alternative information scenarios:

1. Fisherman's ability with new technology is known from the start
2. Fisherman's ability is initially unknown and inferred over time

Production

An entrepreneur's daily output Y_{it} with the new technology depends on:

1. Individual ability (how skillfully the technology is operated), θ_i
2. Idiosyncratic day-to-day risk

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Financing

- Auctioneer faces opportunity cost of funds of r per Rupiah per day
- Auctioneers operate competitively and have zero expected profits at any date

1) Lending Dynamics with Known Ability

Auctioneer's expected daily revenue from lending D_{it} :

$$\gamma E[Y_{t+1}] = \gamma \theta_i.$$

Auctioneer's daily cost of lending D_{it} :

$$r D_{it},$$

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$$rD_{it},$$

which implies

$$D_{it} = \frac{\gamma}{r}\theta_i \text{ for all } t,$$

i.e. debt equals the net present value of an annuity of expected commission revenues.

Lending dynamics in the absence of ability uncertainty

		Fisherman produces output y_1		Fisherman produces output y_2		
Lender/trader advances $D_0 = \frac{\gamma}{r}\theta$ to fisherman		Lender/trader keeps $(\gamma+\mu)y_1$		Lender/trader keeps $(\gamma+\mu)y_2$		
Fisherman owes D_0		Fisherman owes $\frac{\gamma}{r}\theta - \mu y_1$		Fisherman owes $\frac{\gamma}{r}\theta - \mu y_2$		
Fisherman adopts new technology		Fisherman is granted $D_1 = D_0 = \frac{\gamma}{r}\theta$, i.e. receives a follow up loan of μy_1		Fisherman is granted $D_2 = D_0 = \frac{\gamma}{r}\theta$, i.e. receives a follow up loan of μy_2		

2) Lending Dynamics with Unknown Ability

Learning about Ability

Initially, villagers hold beliefs in the form of a prior about a fisherman's ability,

$$\widetilde{\theta}_{i0} \sim N(\widehat{\theta}_{i0}, h_0^{-2}),$$

$\widehat{\theta}_{i0}$: Mean of initial prior

h_0: Precision (inverse standard deviation) of initial prior

Random effects model:

$$\theta_i = \psi + \nu_i$$

ψ : Common value of new technology, $\widetilde{\psi}_0 \sim N(\widehat{\psi}_0, \sigma_\psi^2)$

Aggregate uncertainty: $\sigma_\psi^2 > 0$

ν_i : Individual-specific deviation from common value, $\nu_i \sim N(0, \sigma_\nu^2)$

Individual-specific uncertainty: $\sigma_\nu^2 > 0$

2) Lending Dynamics with Unknown Ability

Learning about Ability

- m fishermen adopt simultaneously
- Beliefs are updated according to
  1. a fisherman's observed performance up to day t, $\overline{y}_{it}$
  2. aggregate observed performance up to day t, $\overline{\overline{y}}_t$

$$\widehat{\theta}_{it} = w_1(t)\overline{y}_{it} + w_2(t)\overline{\overline{y}}_t + w_3(t)\widehat{\psi}_0$$

Lending Dynamics

a) Full Debt Adjustment

$$D_{it} = \frac{\gamma}{r}\widehat{\theta}_{it}.$$

Testable implications 1: Uncertainty

$$\widehat{\theta}_{it} = w_1(t)\overline{y}_{it} + w_2(t)\overline{\overline{y}}_t + w_3(t)\widehat{\psi}_0$$

1. No individual specific uncertainty:
   $\rightarrow$ initial beliefs about common value have zero variance, $\sigma^2_\psi = 0$
   $\rightarrow$ observed debt does not depend on realized individual performance $\overline{y}_t$; $w_1 = 0$.

2. No aggregate uncertainty
   $\rightarrow$ initial beliefs about individual-specific deviation concentrated, $\sigma^2_\nu = 0$
   $\rightarrow$ observed debt does not depend on realized aggregate performance $\overline{\overline{y}}_t$; $w_2 = 0$.

Lending Dynamics
b) No Downward Debt Adjustment

Repayment share of output $\mu = 0$

$$D_t = \frac{\gamma}{r}\widehat{\theta}_{it} - z(t),$$

where $z(t) > 0,\ z'(t) < 0,\ \lim_{t\to\infty} z(t) = 0$
(Situation similar to Harris and Holmstrom, 1982).

Lending Dynamics

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Testable implications 2: Credit Constraint

- Controlling for learning about profitability, debt has an upward trend for each fisherman, "cautious lending"

Data

- 69 fisherman households of a coastal village in Tamil Nadu
- 11 commercial and 3 non-commercial (NGO) auctioneers [excluded from analysis]
- Village population ca. 800, relatively well developed due to good accessibility and receipts from temporary migrants
- Sales and debt data collected from auctioneers in three waves (2002, 2004, 2006)

Descriptive Statistics (34 individuals, $N = 1539$)

	Mean	Std Dev	Minimum	Maximum
Initial Debt	58119.27	23224.10	15069	107796
Debt	59558.26	27018.07	2509	157619
Debt at Renegotiation	60771.97	28056.08	3257	157619
Renegotiation Incidence	0.330	0.470	0	1
Change of Auctioneer	0.008	0.091	0	1
Sales (per Month)	23544.38	18305.19	0	116,960
Month of Adoption	Jan 2002	10.47	January 2001	September 2005

Empirical Analysis

Roadmap

1. Reduced form analysis: Tests for
   - individual-specific uncertainty
   - credit constraint
2. Structural analysis: Tests for
   - aggregate uncertainty
   - individual-specific uncertainty
   - credit constraint

   while controlling for
   - (cross-sectional) unobserved heterogeneity
   - change (over time) in opportunity cost of funds

1) Reduced Form Analysis

a) Testing for individual-specific uncertainty

Debt relative to initial debt

$$\frac{D_{it}}{D_{i0}} = \frac{\widehat{\theta}_{it}}{\widehat{\theta}_{i,0}} = \frac{w_1(t)\overline{y}_{it} + w_2(t)\overline{\overline{y}}_t + w_3(t)\widehat{\psi}_0}{\widehat{\psi}_0}$$

Regression specification:

$$\frac{D_{it}}{D_{i0}} = w_1 \frac{\overline{y}_{it}}{D_{i0}} + \varepsilon_{it}$$

	(1)		(2)		(3)	
	Debt		Debt		Logarithm of Debt	
Constant	1.245	(10.44)	2.511	(8.72)	1.566	(10.42)
Sales (normalized)	1.093	(8.96)			0.690	(5.29)
Sales 1st year			0.212	(0.92)		
Sales 2nd year			0.410	(1.57)		
Sales 3rd year			1.593	(6.5)		
Sales 4th year			1.356	(4.68)		
First year			-1.736	(-4.99)	-1.113	(-5.60)
Second year			-1.517	(-4.34)	-0.811	(-4.39)
Third year			-1.628	(-4.8)	-0.319	(-1.93)
Fourth year			-1.459	(-4.35)	-0.185	(-1.23)
Fifth year			.	.	.	.
Individuals	34		34		34	
Observations	449		449		449	
R-squared	0.228		0.375		0.321	

Notes: t-statistics in parentheses.

1) Reduced Form Analysis

a) Testing for credit constraint

$$D_t = \frac{\gamma}{r}\widehat{\theta}_{it} - z(t),$$

where $z(t) > 0,\ z'(t) < 0,\ \lim_{t\to\infty} z(t) = 0.$

Controlling for learning, debt trends upward

$$\frac{D_{it}}{D_{i0}} = \sum_{k=1}^{5} c_k year sex(k)_{it} + b\frac{\overline{y}_{it}}{D_{i0}} + \varepsilon_{it}$$

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Sales 5th year			-0.706	(-1.79)		
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2) Structural Econometric Analysis

We allow for

- Changing opportunity cost of lender, $r = r(t)$
- Unobserved heterogeneity, $Y_{it} \sim N(x_i\widehat{\theta}_{it}, x_i^2)$,
  where x_i is observed by villagers but not by researcher

$$D_{it} = \frac{\gamma}{r(t)} x_i \zeta(t - t_{i0})\widehat{\theta}_{it} = \frac{\gamma}{r(t)} x_i \zeta(t - t_{i0}) \left[w_1 \frac{\overline{y}_{it}}{x_i} + w_2\widehat{\psi}_t + w_3\widehat{\psi}_0 \right]$$

$\zeta(\tau)$: captures credit constraint
$= 1$ for all τ with unlimited liability

- We estimate

$$\frac{D_{it}}{D_{i0}} = \frac{r(t_{i0})}{r(t)} \frac{\zeta(t - t_{i0})}{\zeta(0)} \left[w_1 \gamma \frac{\overline{y}_{it}}{D_{i0}} \frac{\zeta(0)}{r(t_{i0})} + (1 - w_1) \frac{\widehat{\psi}_t}{\widehat{\psi}_{ti0}} \right],$$

  where $r(t)$, $\zeta(\tau)$, $\widehat{\psi}_t$ are parametrized.

- Method: NLS

	(1)		(2)	
ψ 2001	0.000	.	0.000	.
ψ 2002	-1.181	(-2.09)	-1.298	(-0.96)
ψ 2003	-1.757	(-2.99)	-1.090	(-0.79)
ψ 2004	-2.602	(-3.54)	-1.347	(-0.92)
ψ 2005	-1.891	(-2.33)	-0.975	(-0.65)
ψ 2006	-1.455	(-1.66)	0.602	(0.35)
w1	0.256	(3.82)		
w1 1st year			0.132	(1.47)
w1 2nd year			0.242	(2.09)
w1 3rd year			0.795	(5.57)
w1 4th year			0.708	(3.63)
w1 5th year			0.708	(3.63)
ζ 1st year	0.000	.	0.000	.
ζ 2nd year	0.454	(4.69)	0.331	(2.91)
ζ 3rd year	0.739	(5.52)	0.562	(1.37)
ζ 4th year	0.659	(3.69)	0.269	(0.75)
ζ 5th year	0.884	(3.61)	0.287	(0.79)
r 2001	-0.144	(-0.33)	0.166	(0.14)
r 2002	-0.793	(-3.34)	-0.792	(-1.82)
r 2003	-1.067	(-4.47)	-0.571	(-1.08)
r 2004	-1.217	(-3.9)	-0.640	(-1.12)
r 2005	-0.776	(-2.03)	-0.558	(-1.00)
r 2006	-0.645	(-1.32)	-0.035	(-0.05)
Individuals	34		34	
Observations	445		445	
R-squared	0.294		0.317	

Findings

- No significant evidence for aggregate uncertainty
- Null hypothesis of individual specific uncertainty rejected
- Null hypothesis of no cautious lending rejected

Discussion

Findings point to two obstacles to technology adoption:

- Initially uncertain individual benefits may prevent a risk averse individual to adopt a profitable new technology
- Non-exclusive contract generates a credit constraint

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Stated Reason for Delayed Adoption	Count
Benefit Uncertainty	14
Credit Constraint	25
Lack of Operational Skills	1
Other	8
Total	48

Discussion

Findings point to two obstacles to technology adoption:

- Initially uncertain individual benefits may prevent a risk averse individual to adopt a profitable new technology
- Non-exclusive contract generates a credit constraint
- According to another data source, fishermen likely do not have informational advantage over auctioneers

Lessons for Policy

- Often criticized interlinking of markets has, overall, been quite successful in the study village for facilitating the technology switch
- Individual benefit uncertainty different from
  1. Aggregate, systematic underprojection of yields (as in Besley and Case, 1994)
     $\rightarrow$ Extension work likely to be effective
  2. Volatility around a known mean (Feder et al., 1985)
     $\rightarrow$ Insurance product feasible
- Credit constraint per se can be mitigated through, e.g., price subsidies on FRPs
- Both of these obstacles affect the poor most drastically
- Increased competition among lenders not necessarily beneficial (Competition makes contracts non-exclusive)