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

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World Bank and Cornell University
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
  → Rural-urban gap widens
- Poor rural households typically most affected
  → 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)
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)

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

Switch from 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
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- 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).
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)
- 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
Empirical Setting

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- 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)
- 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
- 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, all 61 FRPs are financed by one of 14 fish auctioneers
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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 $\gamma$ (7%) of sales revenue as commission and a share $\mu$ (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 → Borrower cannot commit to lender.
### Dynamics of the debt contract

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

![Time in days, $t$](image)
Implication

• Additional debt is costless for fisherman

• Fisherman has incentive to ask for as much additional debt as he is granted at any date
Implication

- Additional debt is costless for fisherman
- 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), $\theta_i$
2. Idiosyncratic day-to-day risk
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Stochastic Process:

$$Y_{it} \sim N(\theta_i, 1)$$
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An entrepreneur’s daily output $Y_{it}$ with the new technology depends on:

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

Stochastic Process:

$$Y_{it} \sim N(\theta_i, 1)$$

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 $D_{it}$:

$$r D_{it},$$
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 $D_{it}$:

$$rD_{it},$$

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

<table>
<thead>
<tr>
<th></th>
<th>Fisherman produces output ( y_1 )</th>
<th>Fisherman produces output ( y_2 )</th>
</tr>
</thead>
</table>
| **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 is granted \( D_1 = D_0 = \frac{\gamma}{r} \theta \), i.e. receives a follow up loan of \( \mu y_1 \) | Fisherman is granted \( D_2 = D_0 = \frac{\gamma}{r} \theta \), i.e. receives a follow up loan of \( \mu y_2 \) |

<table>
<thead>
<tr>
<th>Time in days, ( t )</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
</tr>
<tr>
<td>1</td>
</tr>
<tr>
<td>2</td>
</tr>
</tbody>
</table>
2) Lending Dynamics with Unknown Ability

Learning about Ability
Initially, villagers hold beliefs in the form of a prior about a fisherman’s ability,

\[ \tilde{\theta}_{i0} \sim N(\widehat{\theta}_{i0}, h_{0}^{-2}), \]

\( \widehat{\theta}_{i0} \): Mean of initial prior
\( h_{0} \): Precision (inverse standard deviation) of initial prior

Random effects model:

\[ \theta_{i} = \psi + \nu_{i} \]

\( \psi \): Common value of new technology, \( \tilde{\psi}_{0} \sim N(\widehat{\psi}_{0}, \sigma_{\psi}^{2}) \)

Aggregate uncertainty: \( \sigma_{\psi}^{2} > 0 \)

\( \nu_{i} \): 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 $t$, $\bar{y}_{it}$
  2. aggregate observed performance up to day $t$, $\bar{y}_t$

  $$\hat{\theta}_{it} = w_1(t)\bar{y}_{it} + w_2(t)\bar{y}_t + w_3(t)\hat{\psi}_0$$
Lending Dynamics

a) Full Debt Adjustment

\[ D_{it} = \frac{\gamma \hat{\theta}_{it}}{r}. \]
Testable implications 1: Uncertainty

\[ \hat{\theta}_{it} = w_1(t)\bar{y}_{it} + w_2(t)\bar{y}_t + w_3(t)\hat{\psi}_0 \]

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

2. No aggregate uncertainty
   → initial beliefs about individual-specific deviation concentrated, \( \sigma^2_\nu = 0 \)
   → observed debt does not depend on realized aggregate performance \( \bar{y}_t \); \( w_2 = 0 \).
b) No Downward Debt Adjustment

Repayment share of output $\mu = 0$

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

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

(Situation similar to Harris and Holmstrom, 1982).
Lending Dynamics

b) No Downward Debt Adjustment

\[ D_t = \frac{\gamma}{r} \theta_{it} - z(t), \]

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

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

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

\[
\frac{D_{it}}{D_{i0}} = \frac{\hat{\theta}_{it}}{\hat{\theta}_{i,0}} = \frac{w_1(t)\bar{y}_{it} + w_2(t)\bar{y}_t + w_3(t)\hat{\psi}_0}{\hat{\psi}_0}
\]

Regression specification:

\[
\frac{D_{it}}{D_{i0}} = w_1 \frac{\bar{y}_{it}}{D_{i0}} + \varepsilon_{it}
\]
<table>
<thead>
<tr>
<th></th>
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<th>(3)</th>
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<tbody>
<tr>
<td>Debt</td>
<td>1.245 (10.44)</td>
<td>2.511 (8.72)</td>
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</tr>
<tr>
<td>Constant</td>
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<tr>
<td>Sales (normalized)</td>
<td>1.093 (8.96)</td>
<td></td>
<td>0.690 (5.29)</td>
</tr>
<tr>
<td>Sales 1(^{st}) year</td>
<td>0.212 (0.92)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sales 2(^{nd}) year</td>
<td>0.410 (1.57)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sales 3(^{rd}) year</td>
<td>1.593 (6.5)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sales 4(^{th}) year</td>
<td>1.356 (4.68)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>First year</td>
<td>-1.736 (-4.99)</td>
<td>-1.113 (-5.60)</td>
<td></td>
</tr>
<tr>
<td>Second year</td>
<td>-1.517 (-4.34)</td>
<td>-0.811 (-4.39)</td>
<td></td>
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<tr>
<td>Third year</td>
<td>-1.623 (-4.8)</td>
<td>-0.319 (-1.93)</td>
<td></td>
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<tr>
<td>Fourth year</td>
<td>-1.459 (-4.35)</td>
<td>-0.185 (-1.23)</td>
<td></td>
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<tr>
<td>Fifth year</td>
<td></td>
<td></td>
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<tr>
<td>Individuals</td>
<td>34</td>
<td>34</td>
<td>34</td>
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<tr>
<td>Observations</td>
<td>449</td>
<td>449</td>
<td>449</td>
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<tr>
<td>R-squared</td>
<td>0.228</td>
<td>0.375</td>
<td>0.321</td>
</tr>
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Notes: t-statistics in parentheses.
1) Reduced Form Analysis

a) Testing for credit constraint

\[ D_t = \frac{\gamma \hat{\theta}_{it}}{r} - z(t), \]

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

Controlling for learning, debt trends upward

\[ \frac{D_{it}}{D_{i0}} = \sum_{k=1}^{5} c_{k,yearsex}(k)_{it} + b \frac{\overline{y}_{it}}{D_{i0}} + \varepsilon_{it} \]
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<tr>
<td>Sales 5\textsuperscript{th} year</td>
<td>-0.706 (-1.79)</td>
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<td></td>
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<tr>
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<td>-1.736 (-4.99)</td>
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Notes: t-statistics in parentheses.
2) Structural Econometric Analysis

We allow for

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

\[
D_{it} = \frac{\gamma}{r(t)} x_i \zeta(t - t_{i0}) \hat{\theta}_{it} = \frac{\gamma}{r(t)} x_i \zeta(t - t_{i0}) \left[ w_1 \frac{y_{it}}{x_i} + w_2 \psi_t + w_3 \psi_0 \right]
\]

\( \zeta(\tau) \): captures credit constraint

\( = 1 \) for all \( \tau \) with unlimited liability
• We estimate

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

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

• Method: NLS
<table>
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<tr>
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<td>(\psi) 2001</td>
<td>0.000</td>
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<tr>
<td>(\psi) 2002</td>
<td>-1.181</td>
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<td>w1 1st year</td>
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<td>0.132</td>
<td>(1.47)</td>
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<tr>
<td>w1 2nd year</td>
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<td>0.242</td>
<td>(2.09)</td>
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<tr>
<td>w1 3rd year</td>
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<td>0.795</td>
<td>(5.57)</td>
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<tr>
<td>w1 4th year</td>
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<td></td>
<td>0.708</td>
<td>(3.63)</td>
</tr>
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<td>w1 5th year</td>
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<td></td>
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</tr>
<tr>
<td>(\zeta) 1st year</td>
<td>0.000</td>
<td></td>
<td>0.000</td>
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<tr>
<td>(\zeta) 2nd year</td>
<td>0.454</td>
<td>(4.69)</td>
<td>0.331</td>
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<tr>
<td>(\zeta) 3rd year</td>
<td>0.739</td>
<td>(5.52)</td>
<td>0.562</td>
<td>(1.37)</td>
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<td>(\zeta) 4th year</td>
<td>0.659</td>
<td>(3.69)</td>
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<td>r 2003</td>
<td>-1.067</td>
<td>(-4.47)</td>
<td>-0.571</td>
<td>(-1.08)</td>
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<td>r 2004</td>
<td>-1.217</td>
<td>(-3.9)</td>
<td>-0.640</td>
<td>(-1.12)</td>
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<td>r 2005</td>
<td>-0.776</td>
<td>(-2.03)</td>
<td>-0.558</td>
<td>(-1.00)</td>
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<td>r 2006</td>
<td>-0.645</td>
<td>(-1.32)</td>
<td>-0.035</td>
<td>(-0.05)</td>
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<tr>
<td>Individuals</td>
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<td>Observations</td>
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<td>R-squared</td>
<td>0.294</td>
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<td>0.317</td>
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</table>
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
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

<table>
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<tr>
<th>Stated Reason for Delayed Adoption</th>
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<td>Credit Constraint</td>
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<td>Lack of Operational Skills</td>
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<td>Other</td>
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<td>Total</td>
<td>48</td>
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</table>
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)
     → Extension work likely to be effective
  2. Volatility around a known mean (Feder et al., 1985)
     → 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)