# Learning about Oneself: Technology Financing in a Tamil Fishing Village

Xavier Giné
World Bank
xgine@worldbank.org

Stefan Klonner
Cornell University
stefan@klonner.de

May 2005

**Abstract:** We study adoption of a costly new technology when the profitability of the new technique differs over individuals and there is uncertainty about these individual-specific differences. We establish that such individual-specific uncertainty results in a financing constraint when debt contracts are characterized by limited liability and limited commitment on the side of the borrower. In data from a Tamil coastal village, in which a new fishing boat became available in 2001, we find significant evidence for individual-specific ability uncertainty. Results suggest that this uncertainty reduces the amount of external finance available for the technology switch by 20%. The resulting need for complementary self-finance creates a wealth threshold, below which adoption, even if profitable, is not feasible. Kuznets-type inequality dynamics result on the middle run.

Keywords: Technology Adoption, Learning, Credit Constraints
JELs: O31, D83, D92

# Introduction

It is generally recognized that the adoption of new technology plays a fundamental role in the development process. In the context of technology adoption by farmers, numerous recent papers have recognized the importance of complementarities and network effects that arise from the necessity of learning to use a new technology efficiently (Bandiera and Rasul, 2004; Conley and Udry, 2002, 2004; Foster and Rosenzweig, 1995). Such social learning about a new technology can give rise to an adoption S-curve and potentially calls for policies that incentivate individual agents to simultaneously adopt a new technology and thus move to a high productivity equilibrium. Another branch of empirically oriented literature on the subject models learning about the profitability of a new technology (Besley and Case, 1993, 1994).

In the field of rural development, researchers' focus has been on the adoption of not overly capital-intensive technologies in agriculture, such as the adoption of HYV seeds, the switch from food to cash crops, or the use of chemical fertilizers. As a consequence, lack of credit is not seen as a major constraint. In this paper, in contrast, we study the financing of the adoption of a capital-intensive new technology by small-scale entrepreneurs.

The objective of this paper is two-fold. First, we provide evidence that the profitability of a new technology may significantly differ over individuals of the same village and that there is substantial uncertainty about these individual-specific differences. Second, when adoption of the new technology is costly, we show how such uncertainty leads to a credit constraint, which arises in the simultaneous presence of limited liability and limited commitment in the borrower-lender relationship.

These insights have important consequences for economic policy. In particular, poor, risk-averse entrepreneurs may not adopt for two reasons. First, uncertain profitability prospects may deter a risk-averse entrepreneur from adoption. Moreover, such individual-specific uncertainty cannot be alleviated by informational externalities of rich entrepreneurs, who adopt first, as hypothesized in Besley and Case (1994) where the new technology has a profitability common to all villagers. Second, the inherent limits to technology financing demonstrated here may make adoption unaffordable for entrepreneurs with low levels of wealth. Both of these effects can give rise to a poverty trap, in which adoption does not occur with wealth below a certain threshold - even if switching to the new technology has a positive net present value.

The novel identifying feature of our analysis is an individual-specific measure of expectations about how profitable a new technology will be. By comparing these expectations with realized profits earned with the new technology, we are able to show that expectations predict actual individual profits with a substantial, non-systematic error. In contrast, all existing work on technology adoption in rural subsistence economies lacks an appropriate measure of villager's expectations about how profitable a new technology will be, at the individual as well as the aggregate level.

Methodologically, our analysis brings together a literature in labor economics on Bayesian learning about a worker's ability (e.g. Jovanovic, 1979), limited liability in interlinked contracts (see Bell and Srinivasan, 1989), and under-investment as a consequence of limited commitment. This latter issue is also known as the "holdup problem", where the impossibility of commitment by the contracting parties not to renegotiate ex-post results in under-investment ex ante (see Che and Hausch, 1999, for a general treatment and Jacoby et al., 2002, for an application to tenure insecurity and farm-plot investments). A peculiar feature of our analysis is that the holdup is a consequence not of hidden action on the side of the agent, but of hidden information on ability types of agents.

Our analysis is motivated by a capital-intensive technological innovation in the small-scale fishing sector of South India, the shift from traditional wooden to modern fibre reinforced plastic (FRP) boats, which, on average, are about fifty percent more profitable as the traditional technology. The scenario we consider is as follows. An entrepreneur, a fisherman, lacks sufficient funds to finance the new technology on his own and is thus forced to rely on external finance. There is limited liability as interest payments and the repayment of the principal have to be generated from operating the new technology. The output, the amount of fish catches on any given day, is a function of two factors. First, a stochastic element, which we take to be the boat owner's luck to find a school of fish or weather conditions. Second, the entrepreneur's inherent ability to operate the new technology, which positively affects expected output. Initially, each fisherman's ability is unknown and can only be estimated by some prior distribution, $G$ say. As the fisherman operates the new technology, both the lender and the fisherman himself learn about his true ability through the amount of output he produces.

Lenders are risk neutral and behave competitively. This implies, first, that lending to an entrepreneur earns an expected profit of zero at any point in time. Second, and more importantly, an entrepreneur always has the option to increase his debt by switching lenders after adoption has occurred and having the new lender settle his outstanding balance. Lenders, in turn, are eager to attract entrepreneurs who already have a record of successful catches.

Under these assumptions, we show, first, that the absence of individual-specific uncertainty about how profitably the new technology will be operated implies that the level of debt advanced to an entrepreneur before adoption is proportional to the net present value of output to be produced with the new technology. After adoption, the level of debt will not be affected by the amount of output actually produced. When individual-specific uncertainty is present, however, the expected net present value of the enterprise and thus debt will be adjusted up or downward as information on the entrepreneur's ability is revealed through the amount of output she produces. Second, when there is a limit to the extent to which debt can be adjusted downward in response to bad news about the entrepreneur's ability, the loan amount advanced to an entrepreneur whose ability is estimated by $G$ is smaller (sometimes substantially) than the amount a lender would advance to the same fisherman with known ability equal to the mean of $G$.

Since an entrepreneur willing to adopt the new technology has to self-finance the difference between the cost of the boat and the amount advanced by the lender, an entrepreneur will not be able to adopt when self-finance is limited - even though the technology switch is economically viable in expectation and no risk aversion is present on either side. Among a population of entrepreneurs whose abilities are distributed according to the known distribution $G$, but the actual ability of each one is unknown, no single entrepreneur may obtain sufficient finance to adopt, although if abilities were known, most entrepreneurs would adopt, thus giving rise to a non-adoption trap. When wealth is distributed across entrepreneurs, sufficiently wealthy entrepreneurs may adopt while poor ones may not. This results in an increase in inequality within a group of entrepreneurs and can, in addition, lead to economically inefficient outcomes if a wealthy but, in expectation, less able entrepreneur adopts but a poor, more able one, does not. This threshold effect, which may be seen as a market failure, can be overcome by an additional line of credit to entrepreneurs or an insurance scheme among lenders.

# 1 The Model

There is an agent, $B$ say, who has the option to adopt a new technology. Adopting the new technology requires a certain fixed cost, $C$ say. In the context of the application studied in this paper, we may think of $C$ as the cost of an FRP. The agent has a certain inherent ability to operate the new technology, which will be denoted by $\theta_0$. Since, before adoption, the agent has never used the technology, $\theta_0$ is initially unknown.

Once adopted, $B$ operates the new technology repeatedly, in our specific application daily. Conditional on $B$'s ability, the output on any given day $t$, $Y_t$ say, is distributed according to the cumulative distribution function $F(y;\theta)$. We may think of $F$ as representing the chances of finding a flock of fish on a given day. We will assume that $F$ has support $[0,\infty)$ and is continuously differentiable in both arguments. The associated density function will be denoted by $f(y;\theta)$. We will assume that $f$ satisfies the monotone likelihood property or MLR for short (see Milgrom, 1981), that is $x > y$ and $\theta_1 > \theta_2$ imply

$$\text{(MLR1)} \quad \frac{f(x;\theta_1)}{f(x;\theta_2)} > \frac{f(y;\theta_1)}{f(y;\theta_2)}. \tag{1}$$

Loosely speaking, MLR states that high versus low ability is relatively more likely the bigger observed output. Output on any given day is independent of effort.

There is a population of risk-neutral principals, who have access to funds at interest rate $(1/\delta)-1$. A principal, $A$ say, may lend to an agent to provide funds for adopting the new technology. Principals operate under competitive conditions and earn zero expected profits. Before $B$ starts to operate the new technology, all principals share a common prior about her ability, whose cdf will be denoted by $G_0(\theta)$. We assume that $G_0$ has support $[0, \infty)$ and is continuously differentiable.

On any given day, the liability of $B$ is limited by the output she produces. More specifically, we assume that $B$ can pay at most a fraction $\gamma$ of each day's output, which will be called interest payment. We consider a scenario where $B$ has no own wealth to finance $C$. External finance can be obtained from $A$. We seek to determine the maximum amount $A$ may advance to $B$.

## 1.1 Lending with Full Commitment

In this section, we consider a contract in which $B$ fully commits to $A$. In this scenario, $A$ lends an amount of $D_0$ to $B$ on day zero in return for the infinite stream of payments $\{\gamma Y_t\}_{t=1}^{\infty}$. In this case, $A$'s zero profit condition implies

$$-D_0 + \sum_{t=1}^{\infty} \delta^t \gamma E_0[Y_t] = 0,$$

where

$$E_0[Y_t] = E_0[Y_1] = \int_0^{\infty} y \widehat{f}_1(y) dy, \; t = 1, 2, \ldots \; .$$

We denote by $\widehat{f}_1(y)$ the unconditional density of $Y_1$,

$$\widehat{f}_1(y) = \int_0^{\infty} f(y; \theta) g_0(\theta) d\theta$$

and by $\widehat{F}_1(y)$ the associated cdf. It follows that the maximum amount $A$ is willing to lend is given as

$$D_0^{FC} = \frac{\delta}{1-\delta} \gamma E_0[Y_1].$$

When there is a population of ex-ante identical agents, whose abilities are iid distributed according to $G_0$, the contract considered in this section ensures that high ability types cross-subsidize low types. To see this, notice that (1) implies that

$$\frac{\partial F(y;\theta)}{\partial \theta} \leq 0,$$

with strict inequality holding almost always (see Milgrom, 1981). In words, higher ability induces first-order stochastic dominance in the distribution of daily output, which in turn implies higher expected output on any given day. Denoting by $E[Y_t|\theta]$ expected output of an agent with ability $\theta$, we may rewrite $D_0^{FC}$ as

$$D_0^{FC} = \frac{\delta}{1-\delta}\gamma \int_0^\infty E[Y_t|\theta] g_0(\theta) d\theta,$$

which illustrates how high types' output compensates $A$ for the performance of low ability types.

## 1.2 Lending with Limited Commitment

When enforcement is limited, $B$ may not be able to fully commit to $A$. We model such limited commitment as follows. As before, $B$ receives an initial loan of $D_0$ from $A$. After the first day of fishing, however, $B$ may approach another principal, $A'$ say, for a loan of $D_1$. If $D_1$ exceeds $D_0$, $B$ will take that loan from $A'$, repay his outstanding debt with $A$, and instantly consumes the remainder. If, on the other hand, $B$ cannot find another principal who is willing to advance at least the amount she currently owes $A$, $B$ will remain a client of $A$. When one assumes that $B$ discounts future income at a higher rate than $A$, $B$ will always find such behavior profitable. To keep the analysis tractable, we will further assume that after the first day, $B$ is fully committed to his current principal, that is she cannot switch lenders later on.

We solve this problem backwards. First, we address the issue of learning about the agent's type through the amount of output produced on the first day. After the first day of fishing, the posterior density about $B$'s ability is given by

$$g_1(\theta; y_1) \equiv \frac{f(y_1;\theta)g_0(\theta)}{\int\limits_0^\infty f(y_1;\theta)g_0(\theta)d\theta},$$

where $y_1$ denotes $B$'s (realized) output on the first day. Notice that MLR ensures that the associated cdf $G_1(\theta; y)$ first-order statistically dominates $G_1(\theta; x)$ if $x < y$ (see Milgrom, 1981).

We further define the probability density of output conditional on $y_1$ as

$$\widehat{f}_2(y; y_1) = \int\limits_0^\infty f(y;\theta)g_1(\theta; y_1)d\theta.$$

Zero profits on the side of the principal imply

$$-D_1 + \sum_{t=2}^{\infty} \delta^{t-1}\gamma E_1[Y_t|Y_1 = y_1] = 0,$$

where

$$E_1[Y_t|Y_1 = y_1] = E_1[Y_2|Y_1 = y_1] = \int\limits_0^\infty y\widehat{f}_2(y; y_1)dy,\ t = 2, 3, \dots\ .$$

This gives

$$D_1(y_1) = \frac{\delta}{1-\delta}\gamma E_1[Y_2|Y_1 = y_1].$$

We will model lending in period zero a little more generally than in the previous subsection by allowing for some additional liability of $B$. In particular we consider a contract, where, as before, $A$ initially advances $D_0$ to $B$. In return, $B$ not only makes a payment of $\gamma Y_1$ to $A$ but is also liable for her debt up to a limit of $\mu Y_1^a$, where $a$ is a parameter which may assume values on $(0, 1]$. The interpretation of $a$ runs as follows: if $a = 1$, $B$ is liable for her debt up to a fraction $\mu$ of the output on day one - in addition to the interest payment $\gamma Y_1$. As $a$ approaches zero, $\mu$ represents a limit up to which $B$

is liable for her debt independent of realized output on day one. In practice, $\mu$ may then represent the amount of collateral furnished by $B$.

The timing of events is as follows: $A$ advances an amount of $D_0$ to $B$ on day zero. On day one, $B$ produces output $y_1$. $A$ keeps $\gamma y_1$ as interest and reduces $B$'s debt by $\mu y_1^a$. If $B$ finds a lender who is willing to lend more than $D_0 - \mu y_1^a$ to him, she switches lenders, pays off $A$ and consumes the difference $D_1(y_1) - (D_0 - \mu y_1^a)$. Zero profits for lenders now give

$$-D_0 + \delta E_0 \left[\gamma Y_1 + \mu Y_1^a + \min\left(D_0 - \mu Y_1^a, D_1(Y_1)\right)\right] = 0. \quad (2)$$

When $B$ finds another lender who is willing to advance more than $D_0 - \mu y_1^a$, $A$ has a payoff of $\gamma y_1 + D_0$ on day one. If, however, $D_1(y_1) < D_0 - \mu y_1^a$, $A$ will keep $B$ and, at $t = 1$, $B$ has an expected net present value of $D_1(y_1)$. Notice that when $B$'s liability for her debt is unlimited, that is as $\mu$ approaches infinity, the min expression in (2) collapses to $D_0 - \mu Y_1^a$ and $D_0$ equals $D_0^{FC}$.

We are now in a position to state the main result of this section.

**Proposition 1** *If commitment is limited and ability unknown,*
*(i)* $D_0 < D_0^{FC}$ *when there is limited liability, that is when* $\mu$ *is finite;*
*(ii)* $D_0$ *is increasing in the extent of* $B$*'s liability,* $\frac{dD_0}{d\mu} > 0$*;*
*(iii)* $D_0 = D_0^{FC}$ *when liability is unlimited, that is as* $\mu$ *approaches infinity.*

**Proof.** We start with the proof of (iii). Equation 2 evaluated at $D_0 = D_0^{FC}$ can be rewritten as

$$-D_0^{FC} + \delta E_0 \left[\gamma Y_1 + \min\left(D_0^{FC}, D_1(Y_1) + \mu Y_1^a\right)\right] = 0.$$

We will first show that for

$$\forall \varepsilon > 0 \; \exists \widetilde{\mu} \text{ such that for all } \mu > \widetilde{\mu} \;\; \Pr\left(D_0^{FC} > D_1(Y_1) + \mu Y_1^a\right) < \varepsilon. \quad (3)$$

Choosing $\widetilde{\mu} = D_0^{FC}/\widehat{F}_1^{-1}(\varepsilon)^a$ we obtain

$$
\begin{aligned}
\Pr\left(D_0^{FC} > D_1(Y_1) + \widetilde{\mu}Y^a\right) &= \Pr\left(D_0^{FC} > D_1(Y_1) + D_0^{FC}\left(\frac{Y_1}{\widehat{F}_1^{-1}(\varepsilon)}\right)^a\right) \\
&> \Pr\left(D_0^{FC} > D_0^{FC}\left(\frac{Y_1}{\widehat{F}_1^{-1}(\varepsilon)}\right)^a\right) = \Pr\left(\widehat{F}_1^{-1}(\varepsilon) > Y_1\right) \\
&= \widehat{F}_1\left(\widehat{F}_1^{-1}(\varepsilon)\right) = \varepsilon.
\end{aligned}
$$

This, together with the fact that $\Pr\left(D_0^{FC} > D_1(Y_1) + \mu Y^a\right)$ is increasing in $\mu$, establishes (3).

From (3) it follows that $-D_0^{FC} + \delta E_0\left[\gamma Y_1 + \min\left(D_0^{FC}, D_1(Y_1) + \mu Y_1^a\right)\right]$ approaches $-D_0^{FC}(1-\delta) + \delta\gamma E_0[Y_1] = 0$ as $\mu$ approaches infinity, which completes the proof of (iii).

To proof (ii), define $H(y,\mu) = D_1(y) + \mu y^a$,

$$
\Psi(D_0, y, \mu) = -D_0^{FC} + \delta\left(\gamma E_0[Y_1] + \left(1 - \widehat{F}_1(y)\right)D_0 + \int_0^y H(t,\mu)\widehat{f}_1(t)\,dt\right),
$$

$$
\Phi(D_0, y, \mu) = -D_0 + H(y,\mu),
$$

and notice that (2) is equivalent to

$$
\Psi(D_0, y, \mu) = \Phi(D_0, y, \mu) = 0. \tag{4}
$$

Since, evaluated at the solution to (4), $\frac{\partial\Psi(D_0,y,\mu)}{\partial y} = 0$, we have that

$$
\frac{dD_0}{d\mu} = -\frac{\frac{\partial\Psi(D_0,y,\mu)}{\partial\mu}}{\frac{\partial\Psi(D_0,y,\mu)}{\partial D_0}},
$$

where

$$
\frac{\partial\Psi(D_0,y,\mu)}{\partial D_0} = -1 + \delta\left(1 - \widehat{F}_1(y)\right) < 0 \tag{5}
$$

and

$$\frac{\partial\Psi(D_0,y,\mu)}{\partial\mu} = \delta\int\limits_0^y t^a \widehat{f}_1(t)\,dt > 0,$$

which establishes (ii).

Part (i) follows immediately from (ii) and (iii). ■

The first part of this proposition states that the simultaneous presence of limited liability and limited commitment together with uncertainty about the agents type lead to a lower initial debt level than when the agent can fully commit to the principal/lender. The intuition behind this result is that, unlike in the case of full commitment where high types cross-subsidize low types, an agent with high output on the first day is able to ex post capitalize on these news about her ability by extracting additional debt from a lender. On the other hand, due to limited liability, there are cases in which the lender fails to adjust the debt of an agent whose produces little on the first day to a level that corresponds to the agent's estimated ability. The initial debt level thus anticipates the fact that a lender will be "stuck" with a low type with positive probability, while he will lose an agent with high output after the first day as her client. We will refer to the result stated in part (i) as "cautious lending" by the principal.

The third part of Proposition 1, on the other hand, portrays a scenario in which the agent's liability is unlimited. In that case, the lender succeeds in fully adjusting debt to the updated expected net present value of his future interest payments after output on the first day is observed. In consequence, zero expected profits imply that, on day zero, each agent is granted in full the expected net present of his future interest payments. The second part of Proposition 1 states that, the tighter the limit to the agent's liability, the more cautious the principal will be in her lending.

## 1.3 Lending with Known Ability

In this section, we contrast the results of the previous section by considering a scenario in which the agent's type is known from the start. As a consequence, output on any given day does not convey any information about the agent's type.

Denoting by $\theta_0$ $B$'s true ability, we now have that

$$D_1(y_1) \equiv D_1 = \frac{\delta}{1-\delta}\gamma E[Y_t], \tag{6}$$

where $E[Y_t] = \int_0^\infty y f(y;\theta_0)dy$. The key result is summarized in the following proposition.

**Proposition 2** *If commitment is limited and ability known, $D_0 = D_0^{FC} = D_1$ independent of $\mu$.*

**Proof.** First notice that when $D_0^{FC} = D_1$,

$$\Pr(D_0^{FC} > D_1 + \mu Y_1^a) = \Pr(D_1 > D_1 + \mu Y_1^a) = 0,$$

and it remains to establish that

$$-D_1 + \delta\left(\gamma E\left[Y_t\right] + D_1\right) = 0,$$

which, by inspection of (6) is readily verified. ■

The Proposition makes clear that limited liability and limited commitment are not an issue when there is no learning about the agent's type. It states that the limited-liability, limited-commitment contract results in the same initial debt level as one with full commitment and unlimited liability. The reason is that a high type cannot capitalize on her high ability ex post. Instead, her ability is fully reflected in her initial debt level. To re-iterate, only the simultaneous presence of limited liability, limited commitment, and unknown ability result in an initial maximum debt level smaller than the expected net present value of the stream of all future interest payments.

## 1.4 Comparative Static Analysis

In this section we maintain the assumptions of section 1.2 and compare lending to agents whose ability is distributed with different initial priors. In particular, we consider a prior of the form $G_0(\theta;\xi,\sigma)$, where $\xi$ parametrizes the location or scale and $\sigma$ the dispersion of $G_0$.

We will assume that $G_0$ satisfies a monotone likelihood ratio property with respect to $\xi$,

$$\text{(MLR2)}\quad \frac{g_0(\theta;\xi,\sigma)}{g_0(\widetilde{\theta};\xi,\sigma)} > \frac{g_0(\theta;\widetilde{\xi},\sigma)}{g_0(\widetilde{\theta};\widetilde{\xi},\sigma)},$$

if $\widetilde{\theta} > \theta$ and $\widetilde{\xi} > \xi$. In words, a relatively high ability is more likely a higher values of $\xi$. As a consequence, the prior gives more weight to higher values of $\theta$ as $\xi$ increases.

For the dispersion parameter $\sigma$, we make the following assumptions.

$$\text{(A1)}\quad \frac{d\widehat{F}_1(y_1)}{d\sigma} \begin{smallmatrix} > \\ \\ < \end{smallmatrix} 0 \text{ for } y_1 \begin{smallmatrix} < \\ \\ > \end{smallmatrix} y_1^m;$$

$$\text{(A2)}\quad \frac{\partial^2 E_1[Y_2|Y_1 = y_1]}{\partial\sigma\partial y_1} \geq 0;$$

$$\text{(A3)}\quad E_1[Y_2|Y_1 = y_1^m] = E_0[Y_1],$$

where $y_1^m$ denotes the median associated with $\widehat{F}_1$. To have $\sigma$ merely affect the dispersion of output, we also assume $\frac{\partial E_0[Y_1]}{\partial\sigma} = \frac{\partial E_0[Y_2]}{\partial\sigma} = 0$. Assumption 1 formalizes a special case of Rothchild-Stiglitz dominance, where the shift of $\widehat{F}_1$ is such that there is a single crossing at the median. Put differently, an increase in $\sigma$ induces a spread of the distribution of $Y_1$ around the median. Assumption 2 states that, as $\sigma$ increases, the expected value of $Y_2$ is more sensitive to information released through output on the first day. The intuition behind this assumption is that, as ability is less precisely estimated by the initial prior, the extent to which $y_1$ affects the posterior increases. Assumption 3 states that when $B$ produces exactly the median of the distribution of $Y_1$, this is neutral information, as it induces a posterior which makes the conditional expected value of $Y_2$ equal to $E_0[Y_1]$.

**Proposition 3** *(i) If $G_0(\theta;\xi,\sigma)$ satisfies MLR2, initial debt is increasing in $\xi$, $\frac{dD_0}{d\xi} > 0$; (ii) If (A1) to (A3) hold, initial debt is decreasing in $\sigma$, $\frac{dD_0}{d\sigma} < 0$.*

**Proof.** (i) Slightly abusing notation, define $\widehat{F}_1(y_1,\xi)=\int\limits_0^\infty F(y_1;\theta)g_0(\theta\,\xi,\sigma)d\theta$. We have that

$$\widehat{F}_1(y_1,\xi)=F(y_1;0)+\int\limits_0^\infty \frac{\partial F(y_1;\theta)}{\partial\theta}(1-G_0(\theta\,\xi,\sigma))d\theta$$

and thus

$$\frac{\partial\widehat{F}_1(y_1,\xi)}{\partial\xi}=-\int\limits_0^\infty \frac{\partial F(y_1;\theta)}{\partial\theta}\frac{\partial G_0(\theta\,\xi,\sigma)}{\partial\xi}d\theta.$$

MLR1 implies that $\frac{\partial F(y;\theta)}{\partial\theta}<0$ for all $y$ and MLR2 implies that $\frac{\partial G_0(\theta\,\xi,\sigma)}{\partial\xi}<0$, which taken together gives

$$\frac{\partial\widehat{F}_1(y_1,\xi)}{\partial\xi}<0. \tag{7}$$

An increase in $\xi$ thus induces first-order stochastic dominance of $\widehat{F}_1$, which implies that

$$\frac{dE_0[Y_1]}{d\xi}>0. \tag{8}$$

Next define

$$g_1(\theta;y_1,\xi)\equiv\frac{f(y_1;\theta)g_0(\theta\,\xi,\sigma)}{\int\limits_0^\infty f(y_1;\theta)g_0(\theta\,\xi,\sigma)d\theta}$$

and $\widehat{F}_2(y_2,y_1,\xi)=\int\limits_0^\infty F(y_2;\theta)g_1(\theta\,\xi,\sigma)d\theta$. We have that

$$\frac{\partial\widehat{F}_2(y_2,y_1,\xi)}{\partial\xi}=-\int\limits_0^\infty \frac{\partial F(y_2;\theta)}{\partial\theta}\frac{\partial G_1(\theta;y_1\,\xi)}{\partial\xi}d\theta.$$

We now show that MLR2 implies $\frac{\partial G_1(\theta;y_1\,\xi)}{\partial\xi}<0$. Notice that MLR2 implies

$$\frac{g_1(\theta;y_1,\xi)}{g_1(\widetilde{\theta};y_1,\xi)}=\frac{f(y_1,\theta)g_0(\theta;\xi,\sigma)}{f(y_1,\widetilde{\theta})g_0(\widetilde{\theta};\xi,\sigma)}>\frac{f(y_1,\theta)g_0(\theta;\widetilde{\xi},\sigma)}{f(y_1,\widetilde{\theta})g_0(\widetilde{\theta};\widetilde{\xi},\sigma)}=\frac{g_1(\theta;y_1,\widetilde{\xi})}{g_1(\widetilde{\theta};y_1,\widetilde{\xi})},$$

if $\widetilde{\theta} > \theta$ and $\widetilde{\xi} > \xi$. This means that, for all $y_1$, $g_1(\theta; y_1, \xi)$ satisfies the MLR property, which implies that an increase in $\xi$ induces first-order stochastic dominance of $G_1$. This in turn implies $\frac{\partial G_1(\theta; y_1\, \xi)}{\partial \xi} < 0$.

Defining $D_1(y_1; \xi) = \frac{\delta}{1-\delta}\gamma \int\limits_0^\infty y \widehat{f}_2(y, y_1, \xi) dy$ and having established that $\frac{\partial \widehat{F}_2(y_2, y_1, \xi)}{\partial \xi} < 0$, it follows immediately that

$$\frac{\partial D_1(y_1,\, \xi)}{\partial \xi} > 0. \tag{9}$$

We next establish that $\frac{\partial D_1(y_1, \xi)}{\partial y_1} \geq 0$. First notice that MLR1 implies that $\frac{\partial G_1(\theta; y_1, \xi)}{\partial y_1} \leq 0$ with strict inequality for at least some $\theta$, i.e. higher output on day one induces first-order stochastic dominance of the posterior. It follows that

$$\frac{\partial \widehat{F}_2(y_2, y_1, \xi)}{\partial y_1} = \int\limits_0^\infty F(y_2; \theta) \frac{\partial G_1(\theta; y_1, \xi)}{\partial y_1} d\theta < 0,$$

which implies that $E_1[Y_2 | Y_1 = y_1]$ is increasing in $y_1$ and, recalling the definition of $H(y_1, \xi)$,

$$\frac{\partial H(y_1,\, \xi)}{\partial y_1} \geq 0 \tag{10}$$

Similar to the proof of Proposition 1 and again abusing notation slightly, we can write

$$\frac{dD_0}{d\xi} = - - \frac{\frac{\partial \Psi(D_0, y, \xi)}{\partial \xi}}{\frac{\partial \Psi(D_0, y, \xi)}{\partial D_0}}$$

because $\frac{\partial \Psi(D_0, y, \xi)}{\partial y} = 0$. It has already been established in (5) that $\frac{\partial \Psi(D_0, y, \xi)}{\partial D_0} < 0$. As to $\frac{\partial \Psi(D_0, y, \xi)}{\partial \xi}$,

$$\begin{aligned} &\frac{\partial \Psi(D_0, y, \xi)}{\partial \xi} \\ = \;& \delta \left( \gamma \frac{\partial E_0[Y_1]}{\partial \xi} - (D_0 - H(y, \xi)) \frac{\partial \widehat{F}_1(y_1, \xi)}{\partial \xi} - \int\limits_0^y \left( \frac{\partial H(t, \xi)}{\partial y_1} \frac{\partial \widehat{F}_1(t, \xi)}{\partial \xi} - \frac{\partial D_1(t, \xi)}{\partial \xi} \widehat{f}_1(t, \xi) \right) dt \right). \end{aligned}$$

Further, from (8), (4), (10), (7), (9) it follows that $\frac{\partial \Psi(D_0,y,\xi)}{\partial \xi} > 0$, which completes the proof of (i).

(ii) We first state a lemma that will be proved later.

Lemma 1. *The value of $y$ solving $\Psi(D_0, y, \sigma) = \Phi(D_0, y, \sigma) = 0$, $y^*$ say, is strictly smaller than $y_1^m$.*

From A2, A3 and Lemma 1 it follows that

$$\frac{dE_1[Y_2|Y_1 = y]}{d\sigma} < 0 \text{ for all } y < y_1^m,$$

which implies

$$\frac{\partial D_1(t,\sigma)}{\partial \sigma} < 0 \text{ for all } y < y_1^m. \tag{11}$$

We have

$$\frac{dD_0}{d\sigma} = - - \frac{\frac{\partial \Psi(D_0,y,\sigma)}{\partial \sigma}}{\frac{\partial \Psi(D_0,y,\sigma)}{\partial D_0}}$$

and it has already been established that $\frac{\partial \Psi(D_0,y,\sigma)}{\partial D_0} < 0$.

$$\begin{aligned} & \frac{\partial \Psi(D_0, y^*, \sigma)}{\partial \sigma} \\ = \;& \delta \left( (D_0 - H(y^*, \sigma)) \frac{\partial \widehat{F}_1(y^*, \sigma)}{\partial \sigma} - \int\limits_0^{y^*} \left( \frac{\partial H(t,\sigma)}{\partial y_1} \frac{\partial \widehat{F}_1(t,\sigma)}{\partial \sigma} - \frac{\partial D_1(t,\sigma)}{\partial \sigma} \widehat{f}_1(t,\sigma) \right) dt \right). \end{aligned}$$

Equation 4 implies that $D_0 - H(y^*, \sigma) = 0$; (10) establishes $\frac{\partial H(t,\sigma)}{\partial y_1} \geq 0$; A1 and Lemma 1 imply $\frac{\partial \widehat{F}_1(t,\sigma)}{\partial \sigma}$ for all $t \leq y^*$ which, together with (11), establishes that $\frac{\partial \Psi(D_0,y^*,\sigma)}{\partial \sigma} < 0$.

Proof of Lemma 1:

Assume first that $y^* = y_1^m$. We obtain

$$\begin{aligned} \Psi(D_0, y_1^m, \sigma) &= -D_0^{FC} \left(1 - \frac{\delta}{2}\right) + \delta \gamma E_0 [Y_1] + \delta \int\limits_0^{y_1^m} H(t,\sigma) \widehat{f}_1 (t,\sigma) \, dt \\ &< \delta \gamma E_0 [Y_1] - D_0^{FC} (1 - \delta) = \delta \gamma E_0 [Y_1] - (1 - \delta) H(y^m, \sigma) \\ &= -(1 - \delta) \mu y_1^{m\ a} < 0, \end{aligned}$$

which contradicts $\Psi(D_0, y_1^m, \sigma) = 0$. Thus $y^*$ cannot equal $y_1^m$. Now notice that

$$\frac{\partial \Psi(D_0, y, \sigma)}{dy} = \delta(H(y,\sigma) - D_0) \begin{smallmatrix} < \\ > \end{smallmatrix} 0 \text{ if, and only if, } y \begin{smallmatrix} < \\ > \end{smallmatrix} y^*. \tag{12}$$

Further

$$\frac{\partial \Psi(D_0^*, y_1^m, \sigma)}{\partial y} = \delta\left(D_0^{FC} + \mu y_1^{m\ a} - D_0^*\right),$$

and, according to Proposition 1, $D_0^{FC} > D_0^*$. This implies that $\frac{\partial \Psi(D_0^*, y_1^m, \sigma)}{\partial y} > 0$, which, together with (12), establishes the claim. ■

The first part of the proposition states that an agent whose prior attributes more weight to higher ability is eligible for higher initial debt, which is perfectly in accordance with economic intuition. The second part states that increased dispersion of the prior which leaves expected output unaffected will result in lower initial debt. This is because higher dispersion in the prior increases the lender's probability of being stuck with an agent whose updated net present value is lower than the amount she still owes at the end of day one.

## 1.5 Implications for Technology Adoption

In the presence of limited commitment, limited liability and type uncertainty, an agent may fail to adopt the new technology even if this was beneficial from a social perspective. This occurs whenever the cost of the new technology $C$ exceeds the sum of the agent's wealth $W$ and her borrowing capacity $D_0$. In that case, the agent is stuck in a poverty trap, in which lack of initial wealth excludes her from access to a more profitable production technology.

Moreover, in a population of agents whose abilities are ex ante identically distributed but who differ in wealth, this can give rise to an increase in inequality because the relatively wealthy may be able to adopt while the poor may not. Inefficiency may be exacerbated in a population where the expected ability of an agent is negatively correlated with her wealth. Such a scenario can give rise to cases where the on average less able adopt while higher ability types have to continue to use the old technology.

## 2 Empirical Context and the Data

The village of study is located in the southern part of the coast of the gulf of Bengal, close to the pilgrim center of Tiruchendur. With a population of 1,500, there are 75 boats operated by about 250 men. The village has neither a harbor nor a jetty, a fact that restricts operations to beach-landing boats only. All year-round operating vessels have a crew of two to four men and are operated by local households. All of these households belong to the exclusively catholic fishing community of the village, which used to belong to a particular fishermen's caste within the Hindu caste system before collectively converting about 400 years ago.

On a typical day, boats leave the shore around 1am and land at the village's market place on the beach between 7 and 11 in the morning. There, local fish auctioneers market the catches to a group of buyers, which comprise local traders as well as agents of nation-wide operating fish-processing companies.

During the monsoon months, mechanized vollam-boats with a crew of five from other villages land on the village's beach and market their catches there. The local fishing techniques, catamaran and FRP fishing, continue during that period. According to local fishermen, fish is plentiful enough that no competition with the migrating mechanized boats arises. Instead, it is held that the local economy benefits from the demand generated by the migrant crew members and the increased marketing activity in the village.

The catamaran is the traditional fishing technology in southern India. It is a raft-like vessel made of two Alphesia logs tied together with two crossbeams at the two ends. While it was originally powered by either a sail or manpower, all of these boats in our study village were equipped with a 8 or 9 horse power motor by the year 2000.

The beach-landing, fibre-reinforced plastic (FRP) boat is, in contrast, a recent technology. The fibre-reinforced plastic used in these crafts is a composite material comprising a polymer matrix reinforced with glass fibres. This manufacturing technique has been commonly used in aerospace, automotive and marine industries throughout the western hemisphere since the 1950s. It required an intervention of the Indian government, however, to make this technology available to the small-scale fishing sector of Tamil Nadu. In 1995, the Department of Science and Technology of the Indian central government in New Delhi initiated a special project, under which the Centre for Science and Technology and Socio-economic Development in Chennai designed a vessel with active participation by fishermen in more than 20 villages along the 1000-km coastline of Tamil Nadu over the course of four years.

According to the project, the boat was designed to be cost and fuel-effective, versatile, comfortable, and durable to stand the constant exposure to saltwater (Hindu, 2001). In 2000, the boat was made available to fishermen throughout the Tamil Nadu coast. In the context of our study village, it was the opening of a subsidiary of the domestic FRP manufacturer in nearby Tiruchendur in early 2000, which made FRPs readily available. All the FRPs operated in our study village come from this manufacturer and roughly share the same characteristics. Only two boats measure $21\times$ 7 feet, while the rest measures $18\times7$ feet. Fishermen alleged that FRPs can cope with rough surf and are, at the same time, more comfortable, faster and more economical than catamarans. All this indicates that the government project has been successful in achieving its goals. Moreover, the FRP can be powered by the same 8 or 9 hp outboard engine, which was already in common use on catamarans at the time the FRP became available. In most cases, catamaran owners that shifted to FRPs continued to use the outboard engine of the catamaran.

With the same number of crew, an FRP's landings are about 50% bigger than those of a catamaran. Given the yields of fibre-boat fishing, every owner of a catamaran in the village we interviewed assured that he wanted to switch to a fibre boat as soon as possible. It has to be mentioned, however, that fishing on an FRP requires a different set of skills than those needed to operate a catamaran. For that reason it is common practice among the buyers of fibre boats in the village to hire migrant laborer-fishermen from Kerala as crew members who have previously gathered experience with the new technology.

We now turn to the issue of vessel financing. In our study village, it is always the fisherman himself who owns the craft while the bulk of external finance for the purchase of FRPs comes from fish auctioneers who advance loans to boatowners in exchange for the right to market their catches. FRPs are in general not accepted as collateral by banks. There is, moreover, evidence that external finance does typically not cover the amount needed for the technology switch. In our sample, boatowners finance about 35 percent of the cost of the technology switch from own resources.

Despite the presence of credit constraints, we do not observe a fibre boat rental market developed. Presumably, if a rental market for fibre boats existed, credit constraints would be less of an issue as relatively poor but talented fishermen could bypass their lack of funds. According to qualitative interviews conducted in the village, however, it requires great diligence and attention not to damage an FRP and associated gear, such as nets, during operations. In contrast, a hired crew only seeks to maximize catches and according to respondents it cannot be held liable for any damage to the gear or boat. Thus, all respondents agreed that only boat-owning fishermen can make the operation of an FRP economically viable by optimally resolving the trade-off between maximizing daily catches and harming the gear.

We now turn to the marketing of daily fish catches. The credit cum marketing contract commonly observed among recent owners of FRPs derives from a similar contract, which has long prevailed between the owner of a catamaran and an auctioneer. We will therefore start out by briefly describing that latter contract: the auctioneer gives a loan for the purchase of the gear, which at the time of our 2004 interview was between Rs. 15,000 and 25,000. In return, the boatowner has to sell all his daily catches through that auctioneer, who keeps 5 percent of the value of the sales. Depending on the auctioneer, an additional 2 percent may be kept and put into savings account whose balance is refunded to the fisherman in December for the celebration of Christmas and New Year, the major holiday season among the fishermen, who are all catholic. The fisherman does not repay the principal. As a consequence, the commission comprises a compensation for the marketing services as well as an implicit interest payment on the amount owed. Moreover, once in the contract, additional debt is costless for the fisherman since the amount of compensation he pays to the auctioneer is independent of the amount he owes. It thus comes as no surprise that more successful boatowners are granted a larger loan. The contract may be terminated by the boatowner at any time if he can pay off his outstanding loan balance. When a boatowner switches auctioneers, the new auctioneer settles the debt with the previous one. Switching of auctioneers does occur occasionally. According to villagers, the superiority of this interlinked share arrangement over separate debt and marketing contracts is a result of, first, limited liability of the fisherman and, second, costless monitoring of the fisherman's day-to-day success by the auctioneer.[1]

A modified version of this contract is in use for recent owners of FRPs in our study village. In this contract, in addition to a commission of 7 percent, the auctioneer keeps another 10 percent of daily sales, which he deducts from the principal owed by the boatowner. Another 3 percent are kept for the savings account and are refunded in December. The feature of debt reduction allows the auctioneer to adjust the debt level downward when the fisherman's ability to use the new technology turns out to be lower than expected. As modeled in the theory section, however, the contractual terms limit the extent to which such downward adjustment can occur. Unlike a catamaran owner whose level of debt remains constant, an FRP owner asks his auctioneer for additional funds from time to time. If such an additional loan is granted, it is added to the fisherman's outstanding balance and does not bare any extra interest. As in the contract for catamarans, additional debt is thus free for the fisherman. In our data sample of FRP owners, the loan balance is increased every five months on average. If another auctioneer is willing to extend a higher than his current debt balance to a fisherman, he has the option to pay off his present auctioneer with the funds from the other auctioneer and keep the difference for himself.

We finally turn to the fisherman's accounting. Again there is a uniformly observed rule for the division of the proceeds from daily catches. After the fish is auctioned and 80 percent of the sales amount $x$ paid to the boatowner, the boatowner deducts the cost of fuel and bait, $c$, from $0.8x$. Half of the remainder goes to the boatowner and the other half is equally shared among all crew members, including the boatowner if he sails. Each crew member thus receives $(0.8x - c)/(2n)$, where $n$ denotes the number of crew members who sailed on that day, while the boatowner keeps $(0.8x - c)/2$ if he did not

[1] Limited liability is also Basu's (1992) key argument for the predominance of share contracts in agricultural areas of low income countries. Platteau and Nugent (1992) provide a useful general discussion of contract choice in fisheries of low-income economies.

sail and $(0.8x - c)/(2(1 + 1/n))$ if he sailed. To give a realistic example, when the day's catches amount to sales of Rs. 1,000, fuel and bait worth Rs. 200 were used, and a crew of four including the boatowner sailed on the boat, each laborer receives Rs. 75, while the boatowner keeps Rs. 375. The effective payoff to the boatowner is Rs. 405, however, since 30 of the 200 Rupees kept by the auctioneer go toward the boatowner's savings account.

Interestingly, this contractual pattern is used by all nine auctioneers of the village who finance and market FRPs. There is no menue of contracts, which one may expect when the demand for initial finance depends on the fisherman's wealth and wealth varies across fisherman households. As we have shown above, a higher rate of commission in general implies more initial finance. Although economically at times puzzling, uniformity of contractual parameters within a village is a well-documented fact (see e.g. Shaban, 1987, for share contracts in agriculture) and has been attributed to either collective bargaining (Datt, 1996) or bounded rationality (Singh, 1989). Fishermen responded that a higher rate of commission would be usurious and unacceptable.

Information about the success of individual boatowners flows freely since, on every day, all fish is auctioned at the same marketplace and observed by all auctioneers who are present. Moreover, auctioneers keep thorough hand-written records of all sales and loan transactions and, at the end of each year, give a copy of individual sales records to each of their clients. Each boatowner can thus document precisely his record of catches.

We surveyed the study village in 2002 and 2004, collecting detailed lending and sales data from auctioneers. In this version of the paper, we use data from two auctioneers, each of which had six clients with an FRP in January of 2004. The sample underlying the empirical analysis thus comprises a panel of financial data of twelve owners of FRPs and 36 months, the time of the first adoption of a fibre boat in the village, January of 2001, to December 2003. Descriptive statistics are set out in Table 1.

# 3 Empirical Analysis

The goal of this section is to test, first, whether there is evidence for uncertainty about ability and, second, whether initial lending is cautious in the sense of Section 1.2, which is to be taken as evidence for a binding liability limit on the side of the fisherman. We start out, however, by establishing that daily fish sales follow a stationary process, an assumption implicit in the theoretical analysis. Toward this, we estimate

$$y_{it} = a_i + b_1 t + b_2 t^2 + \varepsilon_{it},$$

where $i$ indexes boatowners and $t$ months since adoption. Notice that, for each boatowner, $t$ is counted from the month in which he adopted. There are at least two reasons to expect a positive relationship between time since adoption and sales. First, learning by doing, that is the fisherman operates the new technology more efficiently as he gathers experience. Second, if the price of fish increases over time because of, say, general inflation and catch quantities are stationary.

The results are set out in Table 2. According to the estimates, which are based on 283 data points, the hypothesis of stationary sales cannot be rejected. The Wald test for $b_1 = b_2 = 0$ fails to be rejected at a level of over 40%. The root mean squared error of this estimation equals 10,159, which suggests that the idiosyncratic income risk of FRP fishing is substantial.

Turning to the dynamics of debt, recall that under the hypothesis of type uncertainty, good (bad) news result in an increase (decrease) of debt granted by the auctioneer. For the empirical analysis, we choose cumulative average monthly sales of a boatowner, $\widetilde{y}_{it}$, as summary measure of news. To be precise

$$\widetilde{y}_{it} = \frac{1}{t} \sum_{\tau=1}^{t} y_{i\tau}.$$

The specification we estimate is

$$D_{it} = a_0 + c_1 D_{i0} + c_2 t D_{i0} + c_3 t^2 D_{i0} + d_1 \widetilde{y}_{it} + d_2 t \widetilde{y}_{it} + d_3 t^2 \widetilde{y}_{it} + \beta x_{it} + u_{it},$$

where $D_{it}$ denotes $i$'s debt balance with his auctioneer at time $t$ (again measured in months since adoption) and $x_{it}$ is a vector of controls including $i$'s adoption date, the identity of $i$'s auctioneer as a dummy, and linear and squared terms of $t$. Under the null hypothesis of no type uncertainty, debt at any time is fully explained by $D_{i0}$ and unaffected by $\widetilde{y}_{it}$. Under the alternative hypothesis of learning about ability, $D_{i0}$ results from the initial estimate about $i$'s ability. According to the Bayesian learning model developed in the theory section, as data on $i$'s ability becomes available, debt gradually becomes proportional to $\widetilde{y}_{it}$, which in turn approaches the expected value of $Y_{it}$ by the law of large numbers.

The results of this estimation are set out in Table 3. We estimate two specifications, one with only a linear, and one with linear and squared terms of $t$ with no substantial change in results when the coefficients of interest are concerned. Among the elements of $x_{it}$, only the auctioneer dummy is significant and positively so. Of the two auctioneers in our sample, one is a newcomer who went into business in the year 2000 and it is for that auctioneer that the dummy variable equals one. The estimated coefficient implies that, as an entrant, he grants about 8% more debt to his customers than the incumbent. The insignificant estimated coefficient for date of adoption suggests that the process of debt determination has not significantly changed for later adopters compared to early ones.

Turning to the coefficients of interest, the point estimate of the coefficient on $D_{i0}$ is about 1.2 and not significantly different from unity. Evaluated at the point estimates of specification 1, the polynomial $c_1 + c_2 t + c_3 t^2$ is downward sloping between zero and 17.7, where it attains its global minimum of -0.067. The polynomial $d_1 + d_2 t + d_3 t^2$, on the other hand, is increasing between zero and 16.9, where it equals 1.24.[2] To put this number into perspective, zero profits of auctioneers imply that it equals exactly $\gamma\delta/(1-\delta)$, where $\gamma$ captures the interest rate component of the daily compound commission/interest rate payment and $\delta$ is the auctioneer's monthly discount factor. According to villagers, 2 to 3 of the 7 percent share of the auctioneer in sales is for his marketing efforts. Taking this into account, we arrive at an implied monthly $\delta$ of 0.96 and 0.97, which implies a profit rate of around four percent per month. This is well in accordance with the opportunity cost of capital on the side of auctioneers. One auctioneer, who partly uses funds from

[2] The quadratic polynomials' sections to the right of their stationary points is of course little desirable in the light the theory tested here. Given that the average boatowner adopted only 23 months before the interview date, however, we are confident that the results of Table 3 are mostly driven by those observations where learning is substantial.

an informal money lender to finance his business, cited a monthly interest rate of 3.1%, which leaves just one percent of interest and commission income for other expenses and, if at all, an additional profit margin. This finding provides support for our assumption of perfect competition between auctioneers.

To summarize, the results for $D_{i0}$ and $\widetilde{y}_{it}$ complementarily support our model of learning about ability in three ways. First, the impact of initial information, as reflected by $D_{i0}$, and of news on current debt changes as predicted by the theory over the relevant time period. Second, the two associated estimated polynomials attain their stationary points at almost precisely the same time, 17.7 and 16.9 months, respectively. Third, the derivatives $\frac{dD_{it}}{dD_{i0}}$ and $\frac{dD_{it}}{d\widetilde{y}_{it}}$ evaluated at the stationary points are in remarkable accordance with the equilibrium outcome predicted by the model of known ability.

As formalized in part three of Proposition 1, type uncertainty does not need to result in cautious lending when the agent's debt can be adjusted to the updated estimate about his ability. Moreover, we seek to distinguish between the maintained hypothesis of cautious lending because of type uncertainty and the competing one of an initial systematic underestimation of the potential of the new technology. Support for this latter hypothesis is provided by Besley and Case (1994). Toward this, we estimate

$$D_{it} = a_i + k_1 t + k_2 t^2 + l_1 t \times adoptdate_i + l_2 t^2 \times adoptdate_i + u_{it}, \qquad (13)$$

where $adoptdate_i$ is $i$'s month of adoption. Cautious lending because of type uncertainty implies that the polynomial $k_1 t + k_2 t^2$ is initially increasing and flattens out as $i$'s ability is inferred. Systematic under-estimation of the profitability of the new technology, on the other hand, implies that this polynomial is flatter overall for later adopters because the amount initially granted to later adopters has to reflect upward adjusted beliefs about the general potential of the new technology.

The results are set out in Table 4. The point estimates of $k_1$ and $k_2$ suggest that initial lending is in fact cautious and significantly so. According to specification 1, the estimated polynomial is increasing between zero and 22 months, which is well in accordance with the estimated duration of the learning process implied by the results in Table 3. At the estimated stationary point of $k_1 t + k_2 t^2$, debt is roughly Rs. 12,000 larger than initially, implying a hefty 20% increase over the average initial debt balance. Turning to the test for the presence of a systematically downward-biased initial prior, specification 3, which gives the results of an OLS estimation of (13), suggests that the data used for this analysis is not sufficient to identify all four coefficients of interest. We therefore tried a specification with only a linear interaction term $t \times adoptdate$, whose results are set out in column 2. According to those results, there is some evidence for the Besley/Case hypothesis of initial systematic underestimation of the technology's potential with the estimate of $l_1$ being negative and significantly so. Evaluated at the sample mean, however, there still remains a difference between initial and long-term debt of about Rs. 10,000. Notice, however, that these results are very sensitive to small sample variation, and more data needs to be included in the estimation to arrive at a robust conclusion about this issue.

# 4 Concluding Remarks

We have identified an important feature for the adoption of a new technology whose revenue is highly dependent on the context in which it is operated. For fishermen in a South-Indian village, we have established that individual-specific uncertainty about how successfully an entrepreneur will operate the new technology is substantial and that it takes well over a year until this uncertainty is resolved. Such uncertainty may deter poor entrepreneurs from switching to the new technology for at least two reasons. First, if poor individuals are more reluctant to bear risk than wealthy ones, a poor entrepreneur may not make the technology switch while a wealthy one may. Moreover, since this uncertainty is individual-specific, it cannot be resolved by others who move first, as is the case in models of learning by doing (Foster and Rosenzweig, 1995) or when the new technology has an identical value for all entrepreneurs (Besley and Case, 1994). Instead such uncertainty calls for an insurance scheme for poor entrepreneurs, which mitigates the risk implied by the lack of knowledge about one's own ability. In this connection, it has to be applauded that the observed arrangement through which the new technology, the FRP, is financed, takes the form of a share contract, which shifts part of the risk from the small-scale entrepreneur to a lender/trader, who is in a position to insure individual risks.

On the downside, however, we find that contracts are such that the borrower cannot fully commit to the lender, which results in lenders not being able to fully bundle the risk of individual-specific uncertainty about ability. As a consequence, ex post successful entrepreneurs cross-subsidize unsuccessful ones in only a very limited fashion, which in turn results in reduced initial finance compared to the case of full cross-subsidization. This financial constraint constitutes a second reason for why an entrepreneur is excluded from enjoying the fruits of the new technology: he cannot come up with the funds required for the technology switch. This market imperfection calls for either an insurance scheme for lenders, which mitigates the risk of being locked-in with an ex post unsuccessful entrepreneur, or additional subsidized, uncollateralized credit for entrepreneurs, which makes up for the financing constraint generated by ability uncertainty and limited commitment.

To summarize, we have identified two channels through which individual-specific uncertainty can create a threshold effect and poverty trap. In the absence of policy interventions like insurance schemes or subsidized credit, the scenario portrayed here can create dynamics of sharpening inequality, where initially wealthy households enjoy the fruits of income growth through technological progress, while the poor are excluded.

# References


[1] Bandiera, O. and I. Rasul, 2004. Social Networks and Technology Adoption in Northern Mozambique, unpublished manuscript, London School of Economics.

[2] Basu, K., 1992. Limited liability and the existence of share tenancy, *Journal of Development Economics* 38, 203-220.

[3] Bell, C. and T. N. Srinivasan, 1989. Some aspects of linked product and credit contracts among risk-neutral agents. In P. Bardhan, editor, *The Economic Theory of Agrarian Institutions*. Oxford: Clarendon Press.

[4] Besley, T. and A. Case, 1993. Modeling Technology Adoption in Developing Countries, *American Economic Review* 83, 396-402.

[5] Besley, T. and A. Case, 1994. Diffusion as a Learning Process: Evidence from HYV Cotton, Princeton University Department of Economics Working Paper 5/94.

[6] Che, Y.-D. and D. B. Hausch, 1999. Cooperative Investments and the Value of Contracting, *American Economic Review* 89, 125-147.

[7] Conley, T. G. and C. Udry, 2002. Social learning through networks: The adoption of new agricultural technologies in Ghana, *American Journal of Agricultural Economics* 83, 668-673.

[8] Conley, T. G. and C. Udry, 2004. Learning about a new technology: Pineapple in Ghana, working paper, Yale University.

[9] Datt, G., 1996. Bargaining power, wages and employment: an analysis of agricultural labor markets in India, Sage Publ., New Delhi.

[10] Foster, A. and M. Rosenzweig, 1995. Learning by doing and learning from others, *Journal of Political Economy* 103, 1176-1209.

[11] The Hindu, 2001. Boon for small-scale fishermen, *The Hindu*, March 22, 2001.

[12] Jacoby, H. G,. G. Li, and S. Rozelle, 2002. Hazards of expropriation: Tenure insecurity and investment in Rural China, *American Economic Review* 92, 1420-1448.

[13] Jovanovic, B. 1979. Job Matching and the Theory of Turnover, *Journal of Political Economy* 87, 972-990.

[14] Milgrom, P. R., 1981. Good news and bad news: representation theorems and applications, *Rand Journal of Economics* 12, 380-391.

[15] Platteau, J.-P. and J. Nugent, 1992. Share contracts and their rationale: lessons from marine fishing, *Journal of Development Studies* 28, 386-422.

[16] Shaban, R. A., 1987. Testing between competing models of sharecropping, *Journal of Political Economy* 95, 893-920.

[17] Shing, N., 1989, Theories of Sharecropping, in P. K. Bardhan (ed.), The Economic Theory of Agrarian Institutions, Clarendon Press, Oxford.

Table 1.Descriptive Statistics for the boat-owner sample

| | Mean | Minimum | Maximum | Std Dev |
|---|---|---|---|---|
| **Initial Debt (Rs.)** | 58915.17 | 14386.00 | 135996.00 | 34144.96 |
| **Monthly Sales (Rs.)** | 26520.00 | 4490.00 | 79250.00 | 14000.17 |
| **Month of Adoption** | Jan 2002 | Jan 2001 | Feb 2003 | 9 months |
| **Auctioneer** | 0.5 | 0 | 1 | 0.52 |

**N=12**

Table2. Regression of monthly sales (in Rs.)

| | Parameter Estimate | Standard Error | T Value |
|---|---|---|---|
| **Intercept** | 26720.18 | 2655.44 | 10.06 |
| **Time (in months since adoption)** | -94.02 | 250.11 | -0.38 |
| **Time squared (in months since adoption)** | -0.06 | 7.72 | -0.01 |
| **Boat-owner Fixed Effects** | Yes | | |
| **R-Square** | 0.497 | | |
| **Adj R-Sq** | 0.473 | | |
| **N** | 283 | | |

Table 3. Regression of Debt (in Rs.)

| | (1) | | (2) | |
|---|---|---|---|---|
| | **Parameter Estimate** | **t Value** | **Parameter Estimate** | **t Value** |
| **Intercept** | 163693 | 1.22 | 156069 | 1.16 |
| **Initial Debt** | 1.19876 | 6.63 | 1.17278 | 6.32 |
| **Initial Debt ∗ Time (in Months)** | -0.14331 | -5.13 | -0.13837 | -4.78 |
| **Initial Debt ∗ Time Squared** | 0.00404 | 4.44 | 0.00384 | 3.98 |
| **Cumulative Average Sales** | -1.49914 | -2.86 | -1.56161 | -2.93 |
| **Cumulative Average Sales ∗ Time** | 0.31848 | 4.29 | 0.33409 | 4.27 |
| **Cumulative Average Sales ∗ Time Squared** | -0.00948 | -4.24 | -0.00994 | -4.23 |
| **Date of Adoption (in Months)** | -291.232 | -1.14 | -268.736 | -1.04 |
| **Auctioneer** | 4637.81716 | 2.78 | 4701.05721 | 2.81 |
| **Time** | 882.67373 | 1.94 | -3.43705 | -0.00 |
| **Time Squared** | | | 31.49663 | 0.65 |
| **R-Square** | 0.458 | | 0.459 | |
| **Adj R-Sq** | 0.440 | | 0.439 | |

Table 4. Regression of debt (in Rs.)

| | (1) | | (2) | | (3) | |
|---|---|---|---|---|---|---|
| | **Parameter Estimate** | **t Value** | **Parameter Estimate** | **t Value** | **Parameter Estimate** | **t Value** |
| **Intercept** | 39899 | 8.50 | 40908 | 8.77 | 39788 | 8.19 |
| **Time** | 1075.976 | 2.43 | 2223.464 | 2.68 | 2014.079 | 0.42 |
| **Time Squared** | -24.147 | -1.77 | -48.163 | -2.94 | 852.320 | 0.78 |
| **Time ∗ Adoption Date (in Months)** | | | -68.13 | -2.60 | -22.113 | -0.36 |
| **Time Squared ∗ Adoption Date** | | | | | -54.52 | -0.82 |
| **Fisherman Fixed Effects** | Yes | | Yes | | Yes | |
| **R-Square** | 0.60 | | 0.60 | | 0.61 | |
| **Adj R-Sq** | 0.58 | | 0.58 | | 0.59 | |