Discount rates and credit markets: Theory and evidence from rural India

John L. Pender *

International Food Policy Research Institute, Washington, DC, USA

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Abstract

Three models of credit markets – (1) the permanent income model, (2) upward sloping credit supply to individual borrowers, and (3) constrained credit due to imperfect enforcement – are tested using credit market data and an experimental study of individuals' discount rates in south India. The permanent income model is rejected by both the discount rate and the credit market data. The discount rate data are consistent with either of the other two models, while the credit market data are consistent with a combination of these two models. Other explanations are found to be insufficient to explain the results of this study.

JEL classification: O16; D90

Keywords: Discount rates; Credit constraints; Rural credit markets; Intertemporal choice

1. Introduction

In the past decade, increased concern about problems of resource degradation in developing countries has led to an expanding literature on "sustainable development". One critical factor affecting the sustainability of resource use is the extent to which people discount the future. If the future is heavily discounted, investments that have near-term benefits and long-term costs (e.g., clear-cutting forests) become more attractive and investments that have near-term costs and long-term benefits (e.g., investments in soil conservation) become less attractive. The higher
the discount rate, the faster the optimal rate of depletion of non-renewable resources (Hotelling, 1931) and the lower the optimal steady state stock of a renewable resource (Clark, 1976). In addition, the ability of individuals to cooperate in managing common property resources depends upon how heavily they discount the future. Garrett Hardin's (Hardin, 1968) famous "tragedy of the commons" implicitly assumes that the future is completely discounted by viewing decisions about resource use as a one-shot prisoners' dilemma game. It is well established that in a repeated prisoners' dilemma game, the likelihood of cooperation is greater the less the future is discounted (Kreps, 1990, Ch. 14).

Standard economic theory predicts that if unlimited borrowing or saving at a single riskless rate of interest is possible, individuals optimally would discount future consumption and production at the market interest rate (Fisher, 1930). However, credit may not be available in unlimited quantities at a fixed interest rate if the risk of default increases with loan size or if credit is rationed (Hodgman, 1960; Freimer and Gordon, 1965; Jaffee, 1971; Jaffee and Russell, 1976; Barro, 1976; Keeton, 1979; Stiglitz and Weiss, 1981). As a result, individuals' discount rates may be quite different from observed interest rates, and likely will vary among individuals depending upon their wealth, opportunities, and preferences.

This paper considers three models of credit markets and their implications for discounting and borrowing: (1) borrowers have access to an unlimited supply of credit at a fixed rate of interest (the permanent income model), (2) borrowers face an upward-sloping supply of credit as a result of default risk that increases with the size of the loan, and (3) borrowers face binding credit constraints as a result of limited penalties that can be imposed in event of default. The implications of these models for discount rates and credit market outcomes are derived and tested using an experimental study of discount rates and credit market data from two villages in south India. The first model is rejected both by the discount rate data and by the credit market data. Either the second or third model, or a combination of the two, could be consistent with the discount rate results. Econometric analysis of the credit market data suggests that individual borrowers may face both an upward sloping supply of credit and credit constraints.

Previous experimental studies of individuals' discount rates have reported large deviations of personal discount rates from market interest rates and other anomalies, including findings that measured discount rates fall as the time between rewards increases and when the magnitude of rewards increases (Thaler, 1981; Horowitz, 1988; Benzion et al., 1989; Holcomb and Nelson, 1989). In the present study, these effects were investigated using experiments involving real rewards. As in previous studies, discount rates were found to exceed market interest rates and to decrease with the magnitude of rewards. Discount rates were lower in a 12-month experiment than in a 7-month experiment, but discount rates in longer time frame experiments were not significantly different from those in the 12-month comparison. Explanations for these phenomena that have been provided in previous studies are considered, but found to be insufficient to explain all of the results.
of the present study. Based upon the results of the discount rate experiments as well as analysis of credit market data, I argue that the nature of credit markets in the study villages must be part of the explanation for the results of this study. In particular, this study provides support for the hypothesis that binding credit constraints exist in informal credit markets in rural south India.

2. Discounting and credit markets

The idea that individuals discount the future is an old one in economics, dating back at least to the 19th century (Bohm-Bawerk, 1959). In his original development of the concept, Bohm-Bawerk distinguished discounting that results from diminishing marginal utility of consumption at any point in time, which implies that future consumption may be discounted if present consumption is low; from discounting of the future utility of consumption, termed "impatience" or "positive time preference" (Olson and Bailey, 1981). The former form of discounting is a statement about the effect on the intertemporal marginal rate of substitution of different levels of consumption in the present and future, while the latter relates to the intertemporal marginal rate of substitution when consumption is constant over time. In this paper, "discount rate" will refer to a measure of the intertemporal rate of substitution, which may be affected by either diminishing marginal utility of consumption or pure time preference.

It is well established that if individuals maximize utility and are able to borrow or lend unlimited quantities of consumption goods at a single riskless rate of interest, they will optimally discount at the rate of interest; that is, they will equate their intertemporal marginal rate of substitution to the market rate of substitution. This result was first shown by Fisher (1930) for the case of deterministic consumption, but it holds also when consumption is uncertain, as will be demonstrated below. Thus, a simple test of the hypothesis that borrowers optimally choose intertemporal consumption and have access to unlimited credit at a fixed rate of interest is to measure their discount rates and compare them to the interest rates they pay on their debt. If their discount rates are significantly different from the interest rates they pay, the hypothesis is rejected.

If the above hypothesis is rejected, either individuals are not optimizing or they do not have access to unlimited credit at a fixed rate of interest. Some authors have used theories that discard the assumption of optimization to explain discount rate anomalies. For example, Loewenstein and Thaler (1989) (p. 187) argue that respondents in discount rate experiments may assign small rewards to a mental "checking account" and large rewards to a mental "savings account", and that the marginal propensity to consume out of each account is different, resulting in higher discount rates on small rewards than large rewards (and higher than market interest rates). Clearly, anomalous behavior can be explained using such behavioral theories, though the challenge of applying such theories to actual market
phenomena remains a significant challenge for future research. I take the opposite approach of maintaining that households do optimize, and investigate instead the implications of discarding the assumption of unlimited borrowing at a fixed rate of interest.

I consider two alternative hypotheses to explain the discount rates measured in an experimental study in rural south India. The first alternative assumes that each individual faces an upward-sloping supply of credit, while the second assumes that borrowers face binding credit constraints. Both of the alternatives predict that discount rates may exceed the market rate of interest, but they differ in other implications. Before discussing the implications of these alternatives, I review the implications of the "perfect" credit market model.

2.1. Model 1. Unlimited borrowing at a fixed interest rate

Suppose an individual lives for two periods. In the first period, she chooses how much to borrow ($B$) subject to her initial wealth ($w$). In the second period, her wealth is $z + v$, where $z$ is certain and $v$ is a random variable with density function $f(v)$ and positive support on $[a,b]$. She must repay $(1 + r)B$ to the lender in the second period. Her utility function is additively separable: $U = u_1(c_1) + Eu_2(c_2)$, where $c_1$ and $c_2$ are consumption in the first and second periods, $E$ is the expectation operator, and $u_1$ and $u_2$ exhibit diminishing marginal utility ($u'_1 < 0, u'_2 < 0$) and satisfy Inada conditions. Her optimization problem can be written as:

$$\text{Max}_B u_1(w + B) + Eu_2[z + v - (1 + r)B]$$

The first-order condition for this problem is just the standard perfect market result that the marginal rate of substitution ($u'_1(c_1)/Eu'_2(c_2)$) is equal to the market rate of substitution between present and future consumption $(1 + r)$.

Define the discount rate ($d$) as the rate at which a certain future reward must be discounted to make an individual indifferent between that reward and a certain current reward. Mathematically, if we define the indirect utility function $V(w, z)$ as the function that solves (1), then $d$ is defined implicitly by:

$$V(w + x, z) = V[w, (1 + d)x + z]$$

where $x$ is the present reward and $(1 + d)x$ is the future reward. If $x$ is small, by Taylor's theorem we have:

$$V(w, z) + x \frac{\partial V}{\partial w} \approx V(w, z) + (1 + d)x \frac{\partial V}{\partial z}$$

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1 Later in the paper, I consider the extent to which such theories can explain the evidence available from the villages I studied.

2 These two alternatives are not mutually exclusive, since borrowers may face a binding credit constraint even in the case of an upward sloping supply curve. For purposes of expositional convenience, I shall discuss these as separate cases.

3 This model is essentially the permanent income model.

4 She can also save, in which case $B$ is negative.
Rearranging terms and applying the envelope theorem, we have:

\[ 1 + d = \frac{\partial V/\partial w}{\partial V/\partial z} = \frac{u_1'(c_1)}{E u_2'(c_2)} \]  

(4)

So if the rewards are small, the discount rate is equal to the interest rate. This also will be true if the rewards are large, since all "indifference curves" in \((w, z)\) space are straight lines with slope \(-(1 + r)\).  

This model implies that \(w\) and \(z\) have no effect on discount rates or interest rates. The effects of these variables on borrowing are readily determined:

\[ \frac{dB}{dw} < 0, \quad \frac{dB}{dz} > 0 \]  

(5)

The demand for credit is a decreasing function of current wealth and an increasing function of future income. These are standard results of the permanent income model.

2.2. Model 2. Upward-sloping credit supply

Several authors have demonstrated that if lenders face a risk that the borrower will default and this risk is increasing in the size of the loan, then individual borrowers will face an upward-sloping supply curve for credit (Hodgman, 1960; Freimer and Gordon, 1965; Barro, 1976; Benjamin, 1978; Keeton, 1979; Bell, 1988).  

This situation can result if collateral is not sufficient to cover the cost of loan repayment in all states of nature, either because of income risk or because of uncertainty about the future value of collateral. In this section, I adapt the model of the previous section to allow for the possibility of loan default and derive some of its implications.

In the model of the previous section, if \(v < (1 + r)B - z\) the borrower will not be able to repay the loan. Unless lenders are willing to extend more credit in this circumstance, the loan will be defaulted. More generally, if the borrower is able to keep some amount of wealth in the event of default, say \(c_{\text{min}}\), he will default if \(v < (1 + r)B + c_{\text{min}} - z\).  

For given \(z\), the probability that this occurs will be an increasing function of \(B\) for all \(B\) in the range \([a + z - c_{\text{min}}/(1 + r), b + z - c_{\text{min}}]/(1 + r)\]. If \(B\) is less than this range, default never occurs, and if \(B\) is

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5 $- (\partial V/\partial w)/(\partial V/\partial z)$ is the slope of an "indifference curve" in \((w, z)\) space, and the first-order condition and Eq. (4) imply that this is \(-(1 + r)\) for all positive \(w\) and \(z\). Note that these "indifference curves" are defined in terms of the value function, and thus reflect the individual’s intertemporal opportunities as well as her preferences.

6 Alternatively, borrowers would face an upward supply of credit if they have monopsonistic power with respect to lenders. However, given the much larger number of borrowers than lenders in the Indian villages studied and the limited size of loans to each borrower, this is not a very plausible model.

7 If \(c_{\text{min}} = 0\), people for whom \(u_2(0) = -\infty\) will not borrow if they have positive wealth and there is a positive probability of default, since their expected utility if they borrow would be \(-\infty\). Carroll (1992) makes the same point in the context of a model of precautionary savings.
greater than this range, default always occurs. The interest rate charged by a competitive lender will thus be an increasing function of $B$ (for given $z$) in this range, and no loans larger than $(b + z - c_{\text{min}})/(1 + r)$ will be provided at any interest rate. Holding $B$ fixed, the competitive interest rate will be a declining function of $z$, since increasing $z$ reduces the probability of default. These results are similar to Barro's, with $z$ interpreted as collateral.

Using the same definition of the discount rate as in the previous section, I show in Appendix A that:

$$1 + d = \frac{1 + r + B \frac{\partial r}{\partial B}}{1 - B \frac{\partial r}{\partial z}}$$

The relationship between the discount rate and the interest rate in this model is generally ambiguous. The fact that the credit supply to a borrower is upward sloping means that the marginal cost of a loan is larger than $1 + r$ (by the term $B \frac{\partial r}{\partial B}$), as in the standard monopsony model. This tends to raise the discount rate. On the other hand, the future rewards offered in discount rate experiments have collateral value and thus tend to reduce the competitive interest rate (by the term $B \frac{\partial r}{\partial z}$) and the discount rate. Thus the discount rate may be larger or smaller than the market interest rate in this model.

The effect of current wealth on borrowing in this model is similar to that in Model 1, with equilibrium borrowing a declining function of current wealth. Since the competitive interest rate is not directly affected by current wealth, but is a positive function of borrowing, the interest rate declines with increases in current wealth as borrowing declines:

$$\frac{dB}{dw} < 0, \quad \frac{dr}{dw} < 0$$

The effect of future income on borrowing is ambiguous in general.

2.3. Model 3. Constrained credit

The model of default presented above assumes that lenders' only response to a low income realization is to write off the loan and collect whatever is possible to collect in the current period. However, if enforcement of the loan is perfect and borrowers are sufficiently risk averse – for example, if the penalty of defaulting causes the borrower's utility to be unboundedly negative – the lender could extend the loan indefinitely, adding accumulated interest charges to the original loan, until the borrower eventually repaid the loan. No rational borrower would ever take out

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8 Note that the competitive interest rate will not be a direct function of initial wealth ($w$), though if $B$ is determined by $w$ in equilibrium, the interest rate will be indirectly affected by $w$.

9 Comparative statics results are proved in Appendix A.
a loan for which he had any positive probability of ever defaulting because the expected utility of this would be unboundedly negative. Thus with perfect enforcement and sufficient risk aversion of borrowers, lenders would not need to be concerned with default risk and we are back in the unconstrained borrowing world of Model 1.  

Suppose instead that there is a maximum penalty that can be imposed on borrowers if they default. It may be the forfeiture of an explicit amount of collateral, the imposition of some degree of pain or disgrace upon the borrower, or simply the loss of the ability to borrow from the lender in the future. Let \((1 + r)B_{\text{max}}\) denote the monetary equivalent value of this punishment to the borrower. Then the borrower will repay the loan as long as the cost of repayment \((1 + r)(1 + r)B\) is less than or equal to \((1 + r)B_{\text{max}}\). If lenders are competitive and know a borrower’s value of \((1 + r)B_{\text{max}}\), they will charge a fixed interest rate \(r\) equal to their opportunity cost of funds for a loan up to \(B_{\text{max}}\), and provide no loans larger than \(B_{\text{max}}\).

This model of credit rationing is based upon imperfect enforcement of contracts, rather than asymmetric information between lenders and borrowers, as is assumed in most models of credit rationing in the literature (Keeton (1979); Stiglitz and Weiss, 1981; Chan and Thakor, 1987). With regard to moneylenders and their clients in the villages of this study, the problem of asymmetric information is not likely very critical. The moneylenders in these villages live near their clients, establish long term relationships with them, and are usually well informed about borrowers’ situations and activities, sometimes even advising farmers on the use of productive inputs (Binswanger et al., 1985). Even though they are well informed, moneylenders still must be concerned about their ability to enforce contracts.

The simple model suggested above implies that borrowers will all pay the same fixed interest rate if lenders’ opportunity cost of lending to all borrowers is the same. Of course, transactions and monitoring costs might cause the opportunity cost of lending to vary across borrowers. In addition, if there is a risk that the lender will not be able to impose the penalty if the borrower defaults, the lender may view the penalty as a random variable independent of the size of the loan. In this case, the lender will still charge an interest rate that is independent of the size of the loan, but this rate may vary across borrowers depending upon the lender’s assessment of the probability that each borrower can escape the penalty of defaulting. This generalization changes nothing in the implications discussed below, and is thus not explicitly included in the model.

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\(10\) Indeed, as pointed out in footnote 7, borrowing by highly risk-averse individuals in Model 2 is only tenable if enforcement is limited.

\(11\) If lenders are not certain of the borrower’s valuation of \(B_{\text{max}}\) but know that it falls within some range \([B_{\text{lo}}, B_{\text{hi}}]\), the interest rate will increase with loan size for loans in this range and no loan larger than \(B_{\text{hi}}\) will be offered. This is essentially Benjamin’s (1978) model.
The borrower's optimization problem is:

$$\text{Max}_{B \leq B_{\text{max}}} u_i(w + B) + Eu_2[z + (1 + r)B]$$

(8)

If the credit constraint is not binding, this model is exactly the same as Model 1. Assume that the constraint is binding. Then the first-order conditions imply:

$$1 + r + \frac{\lambda}{Eu_2'(c_2)} = \frac{u_i'(c_1)}{Eu_2'(c_2)}$$

(9)

where $\lambda > 0$ is the lagrangian multiplier for the constraint. With a binding credit constraint, the marginal rate of substitution is greater than $1 + r$.

As before, we apply the envelope theorem to obtain:

$$1 + d = \frac{\partial V/\partial w}{\partial V/\partial z} = \frac{u_i'(c_1) + \lambda \partial B_{\text{max}}/\partial w}{Eu_2'(c_2) + \lambda \partial B_{\text{max}}/\partial z}$$

(10)

The discount rate depends not only on the marginal rate of substitution in this case, but also upon the effect of the rewards offered on the borrowing constraint ($\partial B_{\text{max}}/\partial w$ and $\partial B_{\text{max}}/\partial z$). If increasing current wealth relaxes the borrowing constraint ($\partial B_{\text{max}}/\partial w > 0$), that will tend to increase the attractiveness of additional current wealth and to raise the discount rate. On the other hand, if increasing future wealth relaxes the borrowing constraint ($\partial B_{\text{max}}/\partial z > 0$), that will tend to reduce the discount rate. The net effect of these two tendencies is ambiguous.

It is reasonable to expect that $B_{\text{max}}$ is non-decreasing in the amount of wealth owned by a borrower. The wealthier a person is, the more assets he has that can be used as collateral. Being wealthier may also cause one to place a greater value upon one's reputation, since greater wealth will tend to increase the monetary equivalent value of any normal non-traded good.

If $B_{\text{max}}$ is positive and non-decreasing in wealth, then as $w$ increases the credit constraint must eventually be non-binding at a positive level of borrowing, since the unconstrained demand for credit falls to zero as $w$ rises. Thus borrowing will be non-decreasing in wealth at low levels of wealth, and decreasing in wealth at high levels of wealth when the credit constraint is not binding. When the credit constraint is binding, the marginal rate of substitution falls as $w$ increases. This causes a tendency for the discount rate to fall with increasing wealth, though the net effect of wealth on the discount rate depends upon how $\partial B_{\text{max}}/\partial w$ and $\partial B_{\text{max}}/\partial z$ are affected by changes in $w$.

2.4. Summary

To summarize the implications of these models, Model 1 contains the strongest implications for discount rates, implying that measured discount rates will be equal to the market interest rate, regardless of the size of rewards offered in the experiment. In Models 2 and 3, measured discount rates may be different than market interest rates. Though unambiguous predictions about discount rates are not
possible with Models 2 and 3, there is a tendency for discount rates to fall with wealth in both models as the notional credit demand falls.

Based upon observations of discount rates alone, it is difficult to distinguish between Models 2 and 3. However, these models differ in their implications for credit market outcomes. Model 2 predicts that borrowing will decline with increases in wealth, while Model 3 predicts that borrowing will increase with wealth at low levels of wealth, then eventually decline with wealth once the credit constraint is non-binding. Model 2 predicts that interest rates will be a declining function of current wealth, while Model 3 predicts that interest rates will not be affected by current wealth. Model 2 predicts that different individuals may face different interest rates even for loans of the same size, if they have differences in future income or in the amount of wealth they are able to shelter in event of default. Model 3 superficially implies that all individuals face the same interest rate, though a slight generalization of Model 3 is consistent with different individuals facing different interest rates.

These implications will be tested using data on discount rates and credit markets from two villages in south India.

3. Experimental study of discount rates

The study was conducted in two villages in Andhra Pradesh, India - Aurepalle and Dokur - under the auspices of the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT). Ninety-six respondents participated in the original study, conducted in August 1989. Each of these respondents participated in three experiments, as well as responding to questions about credit market transactions. A follow-up study investigating the repeatability of the findings and discount rates using longer time frames was conducted in April and May 1991. The original 48 respondents from Aurepalle plus an additional 28 Aurepalle residents participated in the follow-up study.

A stratified random sample, based on agricultural land area operated, was used to select the respondents. Three-quarters of the respondents are farmers and one-quarter are landless agricultural workers. The majority of the households in the sample are very poor, with an average per capita income of less than $200. Only one-quarter of the sample respondents are literate. Rice is the most important staple food in both villages. 12

3.1. Experimental design

Of the 96 respondents in the original 1989 study, 48 were from each village. Each respondent participated in three experiments. Six experiments were used;

12 Walker and Ryan (1990) provide a detailed description of the study villages.
with one-half of the sample participating in G1, G2, and G3, and one-half participating in G4, G5, and G6. In each experiment, participants were offered a series of eight to ten binary choices between a specified amount of rice to be received at a particular date and alternative amounts received at some other date. For example, in G1, the participant faced a series of choices between 10 kg. in September 1989 or alternative amounts of rice delivered in April 1990: 13

G1:
1. 10 kg in September 1989 or 9 kg in April 1990
2. 10 kg in September 1989 or 10 kg in April 1990
3. 10 kg in September 1989 or 11 kg in April 1990
4. 10 kg in September 1989 or 12 kg in April 1990
5. 10 kg in September 1989 or 13 kg in April 1990
6. 10 kg in September 1989 or 15 kg in April 1990
7. 10 kg in September 1989 or 17 kg in April 1990
8. 10 kg in September 1989 or 20 kg in April 1990

The participant was asked to indicate which alternative he preferred within each choice pair. Each choice was presented on a separate card, and the respondent’s choice was recorded on each card. The cards were presented in the order listed above. The order in which the three experiments were conducted was randomly assigned. After all three experiments were completed, the participant would randomly select one of the cards representing the choices made in the experiments, this selection determining his reward. This procedure was intended to give participants incentive to reveal their preferences.

In G1, the nominal size of the experiment is 10 kg of rice, the time frame is 7 months and the reference date is September 1989. All choices in this experiment include the option of keeping 10 kg of rice in September 1989. In the other experiments, different time frames, sizes of rewards and reference dates were used (Table 1). 14 In G1–G3, the reference date was the earlier date in all choices, while in G4–G6, the reference date was the later date in all choices.

If the participant “crossed over” exactly once from preference for the early reward to preference for the later reward, a range for the discount rate could be inferred. For example, if the respondent preferred the early reward in the first five choices in G1 and the later reward in the last three choices, his rate of substitution between rewards in September 1989 and April 1990 would be between 1.3 and 1.5, implying a discount rate between 45% and 70%. 15 If the participant did not

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13 September and April were chosen as delivery dates because of comparable sized rice harvests occurring in those months, to control for seasonal variations in supply and demand. Rice prices are fairly stable in these villages (see Fig. 8).

14 The choices offered in the experimental games and the order in which they were presented are given in Appendix B.

15 Discount rates were calculated by the formula $d = \ln(\Delta y/\Delta x)/(t - s)$, where the individual is indifferent between a reward of $\Delta x$ at date $s$ and a reward of $\Delta y$ at date $t$. 
Table 1
Structure and responses to the experiments

<table>
<thead>
<tr>
<th>Experiment</th>
<th>Time frame (months)</th>
<th>Magnitude (kg rice)</th>
<th>Reference point</th>
<th>Median discount rate</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>Original study: August 1989</em></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>G1</td>
<td>7</td>
<td>10</td>
<td>Sept. 1989</td>
<td>0.69–0.91</td>
</tr>
<tr>
<td>G2</td>
<td>12</td>
<td>10</td>
<td>Sept. 1989</td>
<td>0.41–0.69</td>
</tr>
<tr>
<td>G3</td>
<td>12</td>
<td>50</td>
<td>Sept. 1989</td>
<td>0.26–0.34</td>
</tr>
<tr>
<td>G4</td>
<td>7</td>
<td>14</td>
<td>April 1990</td>
<td>0.96–1.19</td>
</tr>
<tr>
<td>G5</td>
<td>12</td>
<td>14</td>
<td>Sept. 1990</td>
<td>&gt; 0.69</td>
</tr>
<tr>
<td>G6</td>
<td>12</td>
<td>65</td>
<td>Sept. 1990</td>
<td>0.37–0.49</td>
</tr>
<tr>
<td><em>Follow-up study: May 1991</em></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>H1</td>
<td>7</td>
<td>10</td>
<td>Sept. 1991</td>
<td>0.69–0.91</td>
</tr>
<tr>
<td>H2</td>
<td>12</td>
<td>10</td>
<td>Sept. 1991</td>
<td>0.59–0.69</td>
</tr>
<tr>
<td>H3</td>
<td>19</td>
<td>10</td>
<td>Sept. 1991</td>
<td>0.58–0.69</td>
</tr>
<tr>
<td>H4</td>
<td>24</td>
<td>10</td>
<td>Sept. 1991</td>
<td>0.58–0.69</td>
</tr>
</tbody>
</table>

cross over at least once, the measurement was censored and only an upper or lower bound for the discount rate could be inferred. If the participant crossed over more than once, nothing, apart from the observation of an inconsistent response, could be inferred about his discount rate.  

In the follow-up study conducted in 1991, the original 48 respondents in Aurepalle plus an additional 28 Aurepalle residents participated. Each respondent participated in four experiments (H1–H4). All experiments offered choices between 10 kg of rice in September 1991 and alternative amounts at later dates. The time frames were 7 months, 12 months, 19 months, and 24 months in H1–H4 respectively.

3.2. Experimental results

The median responses to the experiments are shown in Table 1. The median discount rates are quite high: over 50% in the smaller-magnitude experiments. In contrast, the median value of the maximum real interest rate paid on outstanding debt by respondents in 1989 was 18%. Figs. 1–6 compare measured discount rates in G1–G6 to the maximum interest rate paid by respondents who had outstanding debt. Even using the minimum discount rate in the range measured, measured discount rates in all experiments were higher than the maximum interest rates paid by most respondents.

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16 There were seven inconsistent responses in the 1989 study: one in G1, one in G3, three in G4, one in G5 and one in G6. These were excluded from the analysis. There were no inconsistent responses in the 1991 study. Fewer inconsistent responses may have resulted in 1991 because most of the 1991 respondents had participated in the 1989 study and therefore may have understood the procedure more fully.
Interest Rate vs. Discount Rate in G1

* Multiple observations indicated by numbers

Fig. 1. Minimum discount rate in G1 versus maximum interest rate on debt.

Interest Rate vs. Discount Rate in G2

Fig. 2. Minimum discount rate in G2 versus maximum interest rate on debt.
Interest Rate vs. Discount Rate in G3

Fig. 3. Minimum discount rate in G3 versus maximum interest rate on debt.

Interest Rate vs. Discount Rate in G4

Fig. 4. Minimum discount rate in G4 versus maximum interest rate on debt.
Interest Rate vs. Discount Rate in G5

Fig. 5. Minimum discount rate in G5 versus maximum interest rate on debt.

Interest Rate vs. Discount Rate in G6

Fig. 6. Minimum discount rate in G6 versus maximum interest rate on debt.
Median discount rates were higher in the 7-month time frame experiments (G1, G4, and H1) than in the comparable magnitude 12-month experiments (G2, G5, and H2). The small-magnitude 12-month experiments (G2 and G5) had higher median discount rates than the large-magnitude 12-month experiments (G3 and G6). These results are consistent with the findings of other experimental studies of discount rates (Thaler; Benzion et al.; Horowitz; Holcomb and Nelson). However, the time frame effect was not apparent in the longer time frame experiments (H3 and H4), which had the same median discount rate as H2. These findings are tested econometrically below.

There was considerable variation in measured discount rates among the respondents. A few respondents always preferred the later reward, while a third or more of the sample always preferred the earlier reward.\(^\text{17}\)

The possibility that measured discount rates are biased should be considered. In designing the experiments, possible confounding of the discount rate with subjective risk was considered a potential source of bias. If respondents lacked confidence that a promised future reward would actually be paid, they might tend to prefer a current reward irrespective of their actual discount rate. Given ICRISAT’s long experience in the study villages (since 1975), the familiarity of the respondents with the ICRISAT investigators who conducted the experiments (each of whom lived for several years in the villages), and ICRISAT’s record of providing substantial rewards in other experimental studies, such subjective risk was expected to be minimal.\(^\text{18}\) Nevertheless, all of the experiments offered rewards only at future dates, so that to the extent that any future reward faces the same “credibility discount”, this effect was controlled for. Similar high discount rates were measured in the 1991 study after the rewards were paid for the 1989 study, providing strong evidence that the credibility of future rewards did not significantly bias the estimates. Furthermore, the fact that lower discount rates were measured in the larger-magnitude experiments is difficult to reconcile with a significant credibility bias, since one would expect larger rewards to be subject to greater credibility problems.

3.3. Econometric analysis of the experimental data

Maximum likelihood estimation was used to analyze the data, assuming a normally distributed error term. Suppose the discount rate of individual \(i\) in experiment \(g\) is determined by:

\[
d_{gi} = X_{gi} \beta + \epsilon_{gi}, \quad \epsilon_{gi} \sim \text{i.i.d. normal}(0, \sigma^2)
\]

\(^{17}\) The number of respondents who preferred the later reward in every choice was 1 in G1, 0 in G2, 2 in G3, 4 in G4, 3 in G5, and 3 in G6. The number who preferred the earlier reward in every choice was 16 in G1, 20 in G2, 16 in G3, 22 in G4, 27 in G5, and 20 in G6.

\(^{18}\) Binswanger’s (Binswanger, 1981) experimental study of risk aversion in the same villages used in this study paid real rewards of up to Rs 500, comparable to the largest rewards paid in this study.
where $X_{gi}$ is a vector of characteristics of experiment $g$ or individual $i$, and $\beta$ and $\sigma$ are to be estimated. We observe $X_{gi}$ and interval ranges for $d_{gi}$ given by $[l_{gi}, u_{gi}]$, where $l_{gi}$ and $u_{gi}$ denote the lower and upper limit of $d_{gi}$, respectively.

The likelihood function is given by:

$$L = \prod_{gi} \left[ \phi \left( \frac{u_{gi} - X_{gi} \beta}{\sigma} \right) - \phi \left( \frac{l_{gi} - X_{gi} \beta}{\sigma} \right) \right]$$

where $\Phi$ is the standard normal distribution function. Note that since $l_{gi}$ and $u_{gi}$ are observed, $\beta$ and $\sigma$ can be separately identified.

This general model is used for three separate analyses: (1) analysis of the difference between discount rates and maximum interest rates paid by respondent households, (2) analysis of variations in discount rates across sample households as a function of wealth and other household characteristics, and (3) analysis of experimental effects on discount rates.

### 3.4. Comparison between discount rates and interest rates

To test the difference between discount rates and the maximum interest rates paid by respondent households, the following version of the model was estimated:

$$d_{gi} = (\alpha_g + \text{maxint}_g) (1 - \text{noloan}_i) + \delta_g \text{noloan}_i + \epsilon_{gi}$$

where $\text{noloan} = 1$ if the respondent did not have any debt and 0 otherwise, maxint is the maximum interest rate (in real terms) paid on debt by those who have debt, and $\alpha_g$ and $\delta_g$ are parameters to be estimated. $\alpha_g$ represents the mean difference between the discount rate in experiment $g$ and the maximum real interest rate for respondents who have debt, and $\delta_g$ represents the mean discount rate in experiment $g$ for respondents who don't have debt.

The mean discount rate was significantly higher than the maximum real interest rate on outstanding debt for all experiments in the 1989 study (Table 2). This is inconsistent with Model 1. Mean discount rates for those who had no debt were above 50% in all experiments, suggesting that absence of debt was due to credit rationing rather than no demand for credit. This interpretation is supported by the fact that most of those with no debt were poorer than average for the sample. 19

### 3.5. Determinants of variation in discount rates among respondents

The econometric model used to estimate the effects of respondent characteristics on discount rates is that given in Eq. (11), where $X_{gi}$ includes the
Table 2
Comparison of discount rate to maximum interest rate. Maximum likelihood estimates (asymptotic t-statistics in parentheses). Dependent variable: discount rate

<table>
<thead>
<tr>
<th>Parameter</th>
<th>G1</th>
<th>G2</th>
<th>G3</th>
<th>G4</th>
<th>G5</th>
<th>G6</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean of discount rate minus maximum interest rate for respondents with outstanding debt $\alpha_g$</td>
<td>0.674 ** * (7.19)</td>
<td>0.379 ** * (6.64)</td>
<td>0.238 ** * (3.32)</td>
<td>0.908 ** * (5.36)</td>
<td>0.583 ** * (5.01)</td>
<td>0.360 ** * (4.45)</td>
</tr>
<tr>
<td>Mean discount rate for respondents with no debt $\delta_g$</td>
<td>1.226 ** * (5.15)</td>
<td>0.868 ** * (5.48)</td>
<td>0.609 ** * (3.40)</td>
<td>1.390 ** * (3.29)</td>
<td>0.878 ** * (3.24)</td>
<td>0.535 ** * (2.87)</td>
</tr>
</tbody>
</table>

** * Indicates statistical significance at the 1% level.
respondent household's net wealth per capita and the respondent's village, age, sex, and level of education.\textsuperscript{20}

Wealthier respondents had lower discount rates in all experiments, though the results were statistically significant only in G1, G2 and G3 (Table 3). None of the coefficients were statistically significant for G4, G5 and G6, perhaps because there was more censoring in the responses to these experiments, thus reducing the power of the econometric tests. The size of the wealth effect is substantial in many of the experiments, implying that an increase of Rs 10,000 in net wealth per capita results in as much as a 22 percentage point reduction in discount rate. None of the other explanatory variables was statistically significant for any of the experiments.

The assumption that wealth is an exogenous variable in the regressions was tested using Hausman's (Hausman, 1978) procedure.\textsuperscript{21} Exogeneity of net wealth could not be rejected at the 5\% level in any of the regressions. The sensitivity of the regression results to outliers was explored by running the regressions excluding households with net wealth over Rs 200,000 (this excluded one of the respondents that participated in G1–G3 and one that participated in G4–G6). The qualitative results of the regressions are unchanged in these regressions, though the coefficient of net wealth is even more statistically significant in G1–G3, being significant at the 1\% level in all three cases.

3.6. Differences in discount rates across experiments

Unlike the previous two analyses, estimation of experimental effects requires pooling the data across all of the experiments. Since all respondents participated in more than one experiment, it was possible to estimate a fixed effect for each respondent as well as experiment specific effects. This is also desirable, because if fixed effects were not included errors would not likely be independent across the observations for a particular respondent.

The econometric model for this analysis is:

\begin{equation}
\begin{aligned}
d_{gi} &= \alpha_i + \alpha_g + \epsilon_{gi} \\
\end{aligned}
\end{equation}

where \( \alpha_i \) is a respondent specific effect and \( \alpha_g \) is an experiment-specific effect.

\textsuperscript{20} ICRISAT collected data on all of these variables for the respondent households during the summer of 1989, as part of its village-level studies program. Net wealth is defined as the total value of assets minus debt. Assets include land; buildings; livestock; farm implements; stocks of agricultural products, inputs, household items and consumer durables; and financial assets. Details on the procedures used to collect these data are provided in Walker and Ryan (1990) and Singh et al. (1985).

\textsuperscript{21} In this procedure, the predicted value of net wealth was added to the regressions, where net wealth was predicted by the village, age, age\textsuperscript{2}, education, sex, family size, and caste of the respondent. Under the null hypothesis that net wealth is exogenous, the coefficient of predicted net wealth should not be significantly different from zero. This procedure can be used to test for any violation of the orthogonality assumption, including endogenous variables.
<table>
<thead>
<tr>
<th>Determinant</th>
<th>G1</th>
<th>G2</th>
<th>G3</th>
<th>G4</th>
<th>G5</th>
<th>G6</th>
</tr>
</thead>
<tbody>
<tr>
<td>Intercept</td>
<td>0.948 ** ** (2.65)</td>
<td>0.726 ** ** (3.33)</td>
<td>0.491 * (1.75)</td>
<td>0.848 (1.08)</td>
<td>0.445 (0.88)</td>
<td>0.450 (1.43)</td>
</tr>
<tr>
<td>Net wealth per capita (Rs 10,000)</td>
<td>-0.223 ** ** (-2.84)</td>
<td>-0.117 ** ** (-2.38)</td>
<td>-0.150 ** ** (-2.42)</td>
<td>-0.076 (-0.61)</td>
<td>-0.031 (-0.38)</td>
<td>-0.030 (-0.56)</td>
</tr>
<tr>
<td>Age</td>
<td>0.0025 (0.42)</td>
<td>-0.0012 (-0.31)</td>
<td>-0.0010 (-0.20)</td>
<td>0.0140 (1.19)</td>
<td>0.0115 (1.42)</td>
<td>0.0037 (0.77)</td>
</tr>
<tr>
<td>Education</td>
<td>-0.0027 (-0.09)</td>
<td>-0.0135 (-0.69)</td>
<td>-0.0059 (-0.24)</td>
<td>0.0561 (0.92)</td>
<td>0.0181 (0.48)</td>
<td>0.0345 (1.32)</td>
</tr>
<tr>
<td>Sex (male = 1)</td>
<td>-0.0221 (-0.09)</td>
<td>0.0113 (0.08)</td>
<td>0.0924 (0.50)</td>
<td>-0.410 (-0.65)</td>
<td>-0.126 (-0.32)</td>
<td>-0.148 (-0.64)</td>
</tr>
<tr>
<td>Village (Dokur = 1)</td>
<td>0.175 (1.06)</td>
<td>0.111 (1.05)</td>
<td>0.168 (1.30)</td>
<td>0.186 (0.63)</td>
<td>-0.036 (-0.19)</td>
<td>0.085 (0.67)</td>
</tr>
</tbody>
</table>

* Indicates statistical significance at the 10% level.
** Indicates statistical significance at the 5% level.
*** indicates statistical significance at the 1% level.
Table 4
Experimental effects relative to experiment G2. Maximum likelihood estimates (asymptotic t-statistics in parentheses). Dependent variable: discount rate

<table>
<thead>
<tr>
<th>Experiment</th>
<th>Coefficient b</th>
</tr>
</thead>
<tbody>
<tr>
<td>G1</td>
<td>0.161 *** (3.93)</td>
</tr>
<tr>
<td>G3</td>
<td>-0.225 *** (-5.62)</td>
</tr>
<tr>
<td>G4</td>
<td>0.253 *** (4.71)</td>
</tr>
<tr>
<td>G5</td>
<td>0.032 (0.58)</td>
</tr>
<tr>
<td>G6</td>
<td>-0.144 *** (-2.72)</td>
</tr>
<tr>
<td>H1</td>
<td>0.251 *** (6.13)</td>
</tr>
<tr>
<td>H2</td>
<td>0.093 ** (2.26)</td>
</tr>
<tr>
<td>H3</td>
<td>0.093 ** (2.26)</td>
</tr>
<tr>
<td>H4</td>
<td>0.130 *** (3.13)</td>
</tr>
</tbody>
</table>

* Indicates statistical significance at the 10% level.
** Indicates statistical significance at the 5% level.
*** Indicates statistical significance at the 1% level.

a Individual household fixed effects were estimated but are not reported due to space limitations.
b Coefficients are relative to the coefficient for experiment G2, which is set to zero.

Table 5
Results of hypothesis tests of experimental effects

<table>
<thead>
<tr>
<th>Effect</th>
<th>Test constraint</th>
<th>Results of hypothesis test</th>
</tr>
</thead>
<tbody>
<tr>
<td>Time frame</td>
<td>G1 = G2</td>
<td>Rejected at 1% level</td>
</tr>
<tr>
<td></td>
<td>G4 = G5</td>
<td>Rejected at 1% level</td>
</tr>
<tr>
<td></td>
<td>H1 = H2</td>
<td>Rejected at 1% level</td>
</tr>
<tr>
<td></td>
<td>H2 = H3</td>
<td>Not rejected</td>
</tr>
<tr>
<td></td>
<td>H2 = H4</td>
<td>Not rejected</td>
</tr>
<tr>
<td>Magnitude</td>
<td>G2 = G3</td>
<td>Rejected at 1% level</td>
</tr>
<tr>
<td></td>
<td>G5 = G6</td>
<td>Rejected at 1% level</td>
</tr>
<tr>
<td>Repeatability</td>
<td>G1 = H1</td>
<td>Rejected at 5% level</td>
</tr>
<tr>
<td></td>
<td>G2 = H2</td>
<td>Rejected at 5% level</td>
</tr>
</tbody>
</table>

The results of the estimation, with G2 taken as the reference experiment, are reported in Table 4 and the results of hypothesis tests are reported in Table 5. Comparisons of G1 to G2, G4 to G5 and H1 to H2 demonstrate significantly lower discount rates in a 12-month than in a 7-month experiment. However, such time frame effects were not found in comparing longer time frame experiments (H3 to H2 and H4 to H2). This suggests that the higher discount rate in the 7-month experiment may be a result of seasonality in consumption patterns. This hypothesis is considered further below in the discussion of results.

22 Respondent-specific effects are not reported in Table 4 due to space limitations.
Comparisons of G2 to G3 and G5 to G6 demonstrate a significant magnitude effect, with a lower discount rate in the larger-magnitude experiment. This finding is consistent with the findings of Thaler and Benzion et al. and is inconsistent with Model 1. Whether it is consistent with Model 2 or 3 is considered below.

Comparisons of G1 to H1 and G2 to H2 allow investigation of the repeatability of measured discount rates, since these experiments had identical time frame, magnitude, and reference dates. The results indicate higher discount rates in 1991 than in 1989. Unfortunately, background data were not collected in 1991 that would allow testing of any hypotheses about why discount rates might have increased. Nevertheless, the results are not consistent with a strong credibility bias, since such a bias should not have seriously affected the 1991 study, which was conducted after the rewards were paid for the 1989 study.

The results of the discount rate experiments strongly contradict Model 1, but are not inconsistent with Models 2 and 3. Analysis of credit market data from these villages can provide additional insight relative to these data, as well as helping to distinguish between Model 2 and Model 3.

4. Credit markets in the study villages

Village moneylenders are the most important source of credit in the study villages, accounting for 45% of the respondents’ debt in Aurepalle and 50% in Dokur (Table 6). In 1989, there were about 15 large moneylenders in Aurepalle and four in Dokur. They usually charge interest rates between 18% and 36% per annum. Four moneylenders were interviewed for this study; all stated that the

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Table 6
Distribution of debt of sample respondents by source, 1989 (percentage of outstanding debt)

<table>
<thead>
<tr>
<th>Credit source</th>
<th>Aurepalle</th>
<th>Dokur</th>
</tr>
</thead>
<tbody>
<tr>
<td>Commercial bank</td>
<td>29.5</td>
<td>13.2</td>
</tr>
<tr>
<td>Cooperative bank</td>
<td>18.5</td>
<td>16.6</td>
</tr>
<tr>
<td>Moneylender</td>
<td>45.3</td>
<td>50.0</td>
</tr>
<tr>
<td>Employer</td>
<td>4.5</td>
<td>19.3</td>
</tr>
<tr>
<td>Merchant</td>
<td>0.4</td>
<td>0.9</td>
</tr>
<tr>
<td>Friends/relatives</td>
<td>1.8</td>
<td>–</td>
</tr>
</tbody>
</table>

---

23 The figures in Table 6 are fairly similar to those from ICRISAT’s village studies sample between 1975 and 1984, except that commercial banks have increased in their share of lending relative to cooperatives. In 1979–1980, 45% of the credit (by value) in the two villages was provided by moneylenders (Binswanger et al. 1985).

24 None of the respondents was paying less than 18% interest on a loan from a moneylender, and only one respondent in each village was paying more than 36%.

25 In this section, all interest rate figures are in nominal terms. The annual inflation rate in India in 1988–1989 was 6.0% (growth in average CPI from 1988 to 1989).
rate of interest depends upon the reliability of the client and all indicated that there is a maximum loan that they would provide to any client. Complete default on moneylender loans is relatively rare, though some moneylenders complained about a decline in repayment discipline in recent years. Borrowers usually establish a long-term relationship with a single moneylender, and for established clients a precise repayment schedule is often not fixed in advance.

Banks and cooperatives in nearby towns are also important sources of credit in the study villages. The policies of these formal sector institutions are heavily influenced by government regulations. In 1989, the interest rate charged by banks for most agricultural purposes was 10.5%. Most loans require land as collateral, except loans made under special programs to poorer groups. The value attributed to land for collateral purposes often is much lower than its market value. Banks and cooperatives rarely foreclose on collateral assets, despite a relatively high incidence of default. Banks’ collateral requirements thus appear to serve more as a means of rationing limited formal sector credit in the presence of government interest rate restrictions than as a means of ensuring repayment.

Other sources of credit include employers, merchants, friends and relatives. These sources provide a very minor share of credit in Aurepalle, while employers are a significant source of credit in Dokur. All of the loans provided by employers in Dokur were at an 18% interest rate. Generally, credit in the study villages involves explicit interest costs, though some of the credit provided by employers, merchants, friends and relatives at low interest rates may involve implicit payments not measured by the interest rate.

Of the 96 respondents in the 1989 study, 14 had no outstanding debt. Of those that did have debts, most had debts to more than one creditor. There is substantial variation in the interest rates that individual households pay to different creditors, suggesting either that there are hidden costs to the credit provided at lower interest rates or that such credit is rationed. Given the low regulated interest rates on loans provided by banks and cooperatives, rationing of such credit would not be surprising. A more interesting question is whether moneylender credit is subject to binding constraints. The econometric analysis of the next section addresses this question.

4.1. Econometric analysis of credit market data

Fig. 7(a) presents data on outstanding debt versus wealth of the sample respondents, together with the results of a non-parametric kernel regression of

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26 Binswanger et al. estimated that "in any given year, perhaps 5% of clients defaulted completely".
27 Binswanger et al. (1985) note that repayment of loans by established clients "could easily extend to up to 5 years".
28 Political pressures and government debt forgiveness programs are possible reasons why banks rarely foreclose on defaulters.
29 The mean difference between the minimum and maximum interest rate paid by respondents who had more than one loan was 15 percentage points.
these data. 30 Consistent with Model 3, the kernel regression shows borrowing first rising and then falling with wealth, though the fit is not very close. Fig. 7(b) shows the kernel regression together with pointwise 95% confidence intervals. This figure supports the hypothesis that borrowing rises with wealth at low levels of wealth, but does not provide a great deal of confidence regarding whether or at what wealth level borrowing begins to decline. Nevertheless, these results are consistent with Model 3 but not Model 1 or Model 2, which imply that borrowing falls with wealth. A tobit regression on these data, controlling for other variables, including the village, age, sex, education, and household size of the respondent, also is consistent with Model 3, with a significantly positive coefficient of wealth and significantly negative coefficient of wealth squared (Table 7).

30 The kernel estimator used was a Nadaraya–Watson estimator, using the Epanechnikov kernel (Hardle, 1990). The bandwidth was chosen using the method of cross-validation, which asymptotically minimizes the mean integrated square error of the fit. The bandwidth selected by this method was Rs 47,000.
Table 7
Determinants of amount borrowed by respondents. Tobit estimates (asymptotic $t$-statistics in parentheses). Dependent variable: total debt outstanding (Rs 1000). Number of observations = 96

<table>
<thead>
<tr>
<th>Variable</th>
<th>Coefficient</th>
</tr>
</thead>
<tbody>
<tr>
<td>Intercept</td>
<td>2.559 (1.53)</td>
</tr>
<tr>
<td>Net wealth (Rs 1000)</td>
<td>0.0921 *** (4.40)</td>
</tr>
<tr>
<td>Net wealth(^2) (Rs 1000)(^2)</td>
<td>-0.000321 *** (-3.22)</td>
</tr>
<tr>
<td>Village (Aurepalle = 1)</td>
<td>0.260 (0.35)</td>
</tr>
<tr>
<td>Age</td>
<td>-0.0529 * (-1.83)</td>
</tr>
<tr>
<td>Sex (female = 1)</td>
<td>-1.767 (-1.39)</td>
</tr>
<tr>
<td>Education (years)</td>
<td>-0.0201 (-0.14)</td>
</tr>
<tr>
<td>Number in household</td>
<td>0.0203 (0.11)</td>
</tr>
</tbody>
</table>

* Indicates statistical significance at the 10% level.
** Indicates statistical significance at the 5% level.
*** Indicates statistical significance at the 1% level.

Though these results control for observable household differences, there may be unobservable differences between households in terms of their preferences or opportunities that are correlated with the measured characteristics, causing omitted variable bias. To control for this possibility, I use the ICRISAT panel data from the same villages to explore the relationship between wealth and borrowing and wealth and interest rates, incorporating household and year specific fixed effects. Variables like the village, age, sex and education of the household head will be reflected in the household and year fixed effects as long as they do not vary idiosyncratically across households from year to year. To the extent other household differences in preferences, abilities, and opportunities are constant (and can be adequately reflected by an intercept shift), fixed effects will control for these as well.

I apply the econometric model to loans from moneylenders only, assuming that cheaper but rationed forms of credit will be used first. Only when credit demand exceeds an exogenously determined threshold, determined by the amount of cheaper credit available and the cost of the first unit borrowed from the moneylender, will the borrower borrow from the moneylender. Though this threshold can vary among borrowers and from year to year, I assume that it does not change idiosyncratically across borrowers so that the threshold can be captured by household and year fixed effects. The model estimated is a tobit type, in which both loans from moneylenders and the interest rate are observed if the threshold.

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31 The panel data for Dokur cover the years 1977 to 1980. The Aurepalle data cover 1975 to 1984, but no debts are reported for any of the survey households in 1975.
32 A similar assumption is made by Bell et al. (1990) in their exploration of credit rationing in rural Punjab. Kochar (1989) takes an alternative view, suggesting that informal sector credit may be cheaper than formal sector credit. In the villages of this study, the explicit cost of moneylender credit is greater than the explicit cost of formal sector credit (though there may be differences in unobserved costs).
### Table 8

Estimation of fixed effects model for debt and interest rates (asymptotic t-statistics in parentheses)

<table>
<thead>
<tr>
<th>Variable</th>
<th>Moneylender debt</th>
<th>Maximum interest rate</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Aurepalle</td>
<td>Dokur</td>
</tr>
<tr>
<td>Wealth (Rs 1000)</td>
<td>0.1432 * (1.88)</td>
<td>0.05607 (1.59)</td>
</tr>
<tr>
<td>Wealth² (Rs 1000²)</td>
<td>-0.0002609 * * (-2.01)</td>
<td>-4.19E-05 (-1.57)</td>
</tr>
<tr>
<td>Number of observations</td>
<td>349</td>
<td>144</td>
</tr>
</tbody>
</table>

* indicates statistical significance at the 10% level.

* * Indicates statistical significance at the 5% level.

Estimates of fixed effects coefficients are not reported.

Demand is exceeded, but only the fact that the threshold is not exceeded is observed otherwise.

The econometric model is as follows:

\[ r_{it}^* = \alpha_0 + \alpha_1 w_{it} + \alpha_2 w_{it}^2 + u_{it} \]  

(15)

\[ B_{it}^* = \beta_0 + \beta_1 w_{it} + \beta_2 w_{it}^2 + \epsilon_{it} \]  

(16)

\[ B_{it} = B_{it}^* \text{ if } B_{it}^* > 0, \]  

(17)

\[ r_{it} = r_{it}^* \text{ if } B_{it}^* > 0, \text{ unobserved otherwise} \]  

(18)

where \( B \) is amount borrowed from moneylenders, \( r \) is the maximum interest rate, \( w \) is wealth, \( i \) and \( t \) are indexes for household and year, and \( u_{it} \) and \( \epsilon_{it} \) have zero mean and are independent across households, years, and independent of each other. The assumption of independence between \( u_{it} \) and \( \epsilon_{it} \) implies that the equation for \( r \) can be estimated using ordinary least squares on the non-truncated observations, since the truncation rule is not correlated with \( u_{it} \). 33 The equation for \( B \) is a tobit type model, but maximum likelihood estimation of this model with fixed effects yields inconsistent parameter estimates (Honore, 1992). Instead I use Honore's consistent estimator for this model.

The estimation results are presented in Table 8. The coefficients in the debt equation are consistent with the results of Table 7, with a positive coefficient of wealth and a negative coefficient of wealth squared. These coefficients are statistically significant (at least at the 10% level) for Aurepalle, but not for Dokur. The interest rate regression also shows a positive coefficient for wealth and a negative coefficient for wealth squared, with both of these coefficients significant at the 10% level in both villages.

Like the discount rate data, the credit market data reject the permanent income model of unlimited borrowing at a constant interest rate. Neither Model 2 nor

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33 Relaxing this assumption would require estimating the two equations as a system. Procedures for doing this using the estimation approach of Honore (1992) are not available.
Model 3 is fully consistent with these data. The fact that borrowing increases with wealth at low levels of wealth is consistent with Model 3 but not with Model 2. The fact that the interest rate also increases with wealth at low levels of wealth is not consistent with either model. However, it may be consistent with a model that combines Models 2 and 3. This possibility is discussed in the next section.

5. Discussion

The key empirical findings of this study are that: (1) discount rates are greater than the maximum real interest rate paid by most respondents; (2) discount rates are higher in a 7-month experiment than in a 12-month experiment, but are indistinguishable in 12-month, 19-month, and 24-month experiments; (3) discount rates are lower in experiments involving larger rewards; (4) discount rates are a declining function of wealth; and (5) the level of borrowing by respondents and the maximum interest rate on debt increase with wealth at low levels of wealth and decline with wealth at high levels of wealth. Each of these findings is inconsistent with the permanent income model of unconstrained borrowing at a constant interest rate (Model 1). In this section, I consider the extent to which these findings are consistent with Models 2 and 3, as well as alternative explanations for these phenomena.

5.1. Explanations from previous studies

Previous experimental studies of discount rates have documented results similar to findings (1) and (3) above (Thaler; Benzion et al.; Holcomb and Nelson). Such studies have also found discount rates to be a declining function of the time frame of the experiment (Thaler; Horowitz; Benzion et al.). This is similar to finding (2), though the other studies did not find that the discount rate stayed constant for time frames beyond one year. Explanations that have been offered for these phenomena include models of preferences different from the standard discounted utility model (Ainslie, 1975; Loewenstein and Thaler; Loewenstein and Prelec, 1992); differences in mental accounting procedures for large versus small rewards (Loewenstein and Thaler; Shefrin and Thaler, 1988); the implicit risk associated with delayed outcomes (Stevenson, 1986; Benzion, et al.); and the fixed cost or added compensation needed when a receipt is postponed (Thaler; Benzion et al.). If one or a combination of these explanations suffices to explain the results of the present study, there is no need to consider alternative explanations, though other explanations may also be possible. I will consider each of these briefly.

Several authors have argued that time frame effects in discount rate experiments are inconsistent with the discounted utility model of preferences, implying that preferences exhibit dynamic inconsistency in the sense of Strotz (1956) (Thaler; Loewenstein and Thaler; Loewenstein and Prelec). This argument assumes that the results of discount rate experiments reveal something about
intertemporal preferences directly. However, if agents are optimizing an intertemporal utility function, their opportunities for intertemporal arbitrage are also important in determining how they respond to such experiments. Indeed, if Model 1 holds and the rewards being offered are tradable goods, intertemporal preferences are irrelevant to the choices made in discount rate experiments. Thus, when tradable rewards are offered, one must either abandon the assumption that respondents in experimental studies are optimizing, or make some assumptions (either implicit or explicit) about the nature of credit markets. The implicit assumption in some of the previous studies of discount rates appears to be that there are no possibilities for intertemporal arbitrage; that is, no savings or credit market. The present study provides an explicit generalization of that assumption in Model 3, which allows for a credit market with limited borrowing.

The argument based on the notion of mental accounts assumes that individuals assign small windfalls to a checking account and large windfalls to a savings account. If the propensity to consume out of the savings account is lower than the propensity to consume out of the checking account, individuals will exhibit higher discount rates on smaller rewards (Loewenstein and Thaler). This also explains why discount rates may be greater than market rates of interest, even without credit constraints (Shefrin and Thaler). Thus it is difficult to rule out this hypothesis on the basis of discount rate experiments. As Shefrin and Thaler (1988) argue (p. 631), distinguishing between the credit constraint and mental accounting explanations requires a data set with detailed financial information. In particular, they argue that if the credit rationing hypothesis holds, households with significant liquid wealth should not display sensitivity of consumption to current income. Fortunately, other studies of this issue have been conducted using the ICRISAT data from the region of India in which the present study was conducted. Using annual consumption data from the ICRISAT villages (one of which was Aurepalle) to estimate the stochastic Euler equation, Morduch (1990) found that consumption on large farms was not sensitive to current income, while consumption on smaller farms and by landless households was, consistent with the hypothesis of credit constraints. Using seasonal consumption and income data from the same villages, Chaudhuri and Paxson (1994) also find evidence of seasonally binding credit constraints in Aurepalle. In addition, it is not clear how Shefrin and Thaler’s behavioral model would account for the finding in this study that borrowing first rises and then falls with increases in current wealth. Though they don’t address this issue in their paper, their model appears to imply a monotonic relationship between current wealth and borrowing.

A third explanation for some of the observed discount rate results is that respondents assign an implicit risk to future rewards. Benzion, Rapaport and Yagil

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\(^{34}\) Loewenstein (1987) (p. 668) made this point in discussing why earlier empirical work failed to find evidence of savoring and dread.
consider two variants of this hypothesis: the one-period realization (OPR) of risk hypothesis and the multiple-period realization (MPR) of risk hypothesis. The OPR hypothesis implies an initial risk discount of any future reward, while the MPR hypothesis implies risk increasing proportionally in time. As Benzion et al. observe, the MPR hypothesis can account for discount rates being greater than the market rate of interest, but not for time frame effects. The OPR hypothesis can also account for time frame effects, but neither hypothesis explains magnitude effects (p. 283). Thus, neither risk hypothesis is sufficient to explain the results of the current study. Furthermore, as mentioned earlier, the experiments in this study were designed to minimize the potential confounding influence of implicit risk by offering rewards only in the future. If the OPR hypothesis were true, implicit risk would have no effect on the results of this study since all early and late rewards would incorporate the same multiplicative risk factor. Finally, the repeatability of the study results after the rewards were paid from the first study suggests that implicit risk (at least due to any doubts about whether the rewards would actually be paid) was not a major consideration.

The final explanation that has been offered for time frame and magnitude effects is that there is a fixed cost of waiting for a reward (Thaler, p. 206), or equivalently, that individuals require a fixed "added compensation" for postponing a receipt (Benzion et al., p. 274). This explains both time frame and magnitude effects, since with a larger magnitude or longer time frame, the fixed cost becomes less consequential to the calculation of the discount rate, and in the limit as the time frame or magnitude is increased, the discount rate should approach the market rate of interest. This explanation is somewhat appealing, since it explains most of the phenomena discovered by Thaler and Benzion et al., and can be applied to economic transaction costs or to psychic costs of collecting a delayed reward. However, there are a few reasons why this explanation does not suffice to explain the results of the present study. Since all of the rewards paid in this study were not paid until at least one month after the study, if there are fixed costs of waiting (independent of the amount of time waited or the size of the reward), these costs would apply to the early rewards as well as the late rewards. In this case, the magnitude effect will be the reverse of that found in this study, with the discount rate increasing with the magnitude of the rewards. Consider the formula for the measured discount rate, assuming both the early and late rewards include a fixed cost:

\[
\begin{align*}
d &= \frac{\ln \left( \frac{\delta y + F}{\delta x + F} \right)}{\Delta t}
\end{align*}
\]

where \(\delta x\) and \(\delta y\) are the amount of the reward realized by the respondent, \(F\) is the fixed cost of waiting, and \(\Delta t\) is the time frame of the experiment. Note that in the context of unlimited borrowing, \(\delta y/\delta x = 1 + r\), which is constant and greater than one (assuming a positive real interest rate). It is straightforward to show that
with constant $\delta y/\delta x$ and $\Delta t$, $d$ increases as $\delta x$ is increased, from 0 when $\delta x$ is infinitesimally small relative to $F$, to $r$ when $F$ is infinitesimally small relative to $\delta x$.

Another problem with the fixed cost explanation is that it predicts that discount rates will approach $r$ as either the time frame or magnitude of the experiment is increased. Yet we find that discount rates in this study do not decline for time frames greater than 1 year, but remain higher than interest rates and discount rates in the larger magnitude experiments. Neither does it explain why discount rates should be a declining function of wealth. It might be possible to fit the data better if, as suggested by Benzion et al., we generalize the added compensation approach to allow added compensation to depend on the time frame and magnitude of the experiment; but this would not improve our understanding of what causes discount rates to vary as they do.

We have seen that none of the explanations provided in previous studies of discount rates suffices to explain all of the findings of the present study. This is not to assert that none of the mechanisms suggested in those studies can be at work in the villages I have studied, nor is it to assert that some other mechanism must be found to explain the findings of earlier studies. The economic situation of the respondents, the experimental design used, and the empirical results found in this study are sufficiently different from previous studies that different explanations may be warranted for apparently similar phenomena. In particular, consideration of the nature of credit markets in the study villages, in which other authors have found evidence of credit rationing, appears warranted.

5.2. Effect of the nature of credit markets

As noted earlier in this paper, both Models 2 and 3 are consistent with the observation of higher discount rates than interest rates. These models can also help explain the other findings of this study.

5.2.1. Time frame and magnitude effects

Credit constraints may cause consumption seasonality in the study villages. In the presence of binding credit constraints and seasonal income patterns, households will be forced to accumulate and liquidate other assets (buffer stock savings) or to accept seasonal fluctuations in consumption. Though they find a substantial amount of consumption smoothing, Chaudhuri and Paxson also find significant seasonal patterns of consumption in Aurepalle, with 38% of annual consumption expenditures occurring in the top three consumption months. Two alternatives suggested by Chaudhuri and Paxson to explain seasonality in consumption are seasonal variations in prices or interest rates, or seasonality resulting from buffer stock savings behavior. Data are unavailable on seasonal patterns of interest rates.

35 Unfortunately, Chaudhuri and Paxson do not report the monthly consumption figures.
Fig. 8. Paddy prices in Aurepalle: (a) 1975/76 to 1979/80; (b) 1980/81 to 1984/85.

in the study villages, but data on rice prices show little season variation (Fig. 8). Buffer stock savings may occur with or without binding credit constraints, but Chaudhuri and Paxson find evidence of binding credit constraints in Aurepalle (they did not study Dokur) based on excess sensitivity of seasonal consumption to anticipated changes in income.
Consumption seasonality can explain higher discount rates in the 7-month experiment than the longer time frame experiments. Data from Renkow (1988) on quarterly consumption in Aurepalle show that consumption is lower in the quarter including September than in the quarter including April. Consumption from July through September averaged 14% lower than consumption in the following April through June from 1977 through 1983, controlling for annual consumption growth. Given that consumption in the villages appears to be lower in September than in April, one should expect to observe higher discounting between September and April than between September and the following September.

It is easy to imagine preferences that are consistent with observed patterns of discount rates, given the magnitudes of consumption variation that are observed. For example, consider the following utility function:

$$U = \int e^{-\rho t} \frac{c^1 - R}{1 - R} \, dt$$

(20)

with $\rho = 0.5$ and $R = 2.0$. If consumption growth between each September and the following April is 10% and annual consumption growth is 5%, then the discount rates in four experiments having time frames of 7 months, 12 months, 19 months, and 24 months relative to a September reference point (as in H1–H4) would be 0.83, 0.60, 0.68, 0.60, respectively. This example demonstrates that time frame effects for discount rates are not necessarily inconsistent with a discounted utility function having a constant rate of time preference ($\rho$).

Magnitude effects may also be caused by credit constraints. When credit constraints are binding, the “indifference curves” in ($w, z$) space are not generally linear, so there is no reason to expect large-magnitude experiments to have the same discount rate as small ones. However, this does not explain the size and direction of the magnitude effect. Since there is a tendency for discount rates to fall with increases in wealth when credit is constrained, larger-magnitude experiments should tend to have lower discount rates because of the wealth effect. However, even though the rewards offered in the large magnitude experiments were substantial – equivalent to up to Rs 500 – they are small compared to the median net wealth for the sample (Rs 34,000). Based on the regressions in Table 3, a Rs 500 increase in wealth reduces the predicted discount rate by at most 1.1% in any of the experiments. Yet magnitude effects were much larger than this. Thus

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Data from Renkow (1988). The regression estimates using Renkow’s quarterly estimates of non-durable goods consumption are

<table>
<thead>
<tr>
<th>Variable</th>
<th>Coefficient</th>
<th>t-statistic</th>
</tr>
</thead>
<tbody>
<tr>
<td>Consumption</td>
<td>-4334 + 68.9</td>
<td>4.33</td>
</tr>
<tr>
<td></td>
<td>*Crop year</td>
<td>-2.04</td>
</tr>
<tr>
<td></td>
<td>*Q1 - 16</td>
<td>-0.21</td>
</tr>
<tr>
<td></td>
<td><em>Q2 + 85</em> Q3</td>
<td>1.11</td>
</tr>
</tbody>
</table>

where Crop year is the year beginning 1 July (e.g., Crop year = 80 for the year 1 July 1980 to 30 June 1981), Q1 is a dummy variable for the first quarter (1 July to 30 September), etc. Mean consumption for the sample was Rs 1139.
the wealth effect of the large magnitude experiments cannot explain the observed magnitude effects.

An alternative explanation for the magnitude effect is that not all forms of wealth are equally valuable as collateral (Binswanger and Rosenzweig, 1986). Perhaps the future rewards promised in the experiments are viewed as good collateral, while the present reward is not viewed as collateral since it could be easily consumed or sold. The size of the future rewards offered in the large-magnitude experiment may be a much more significant fraction of the collateral owned by the respondent than it is of the respondent’s total wealth. With a binding credit constraint, the value of collateral is equal to the amount borrowed multiplied by \((1 + r)\). Based on the mean level of debt of the sample respondents in 1989 (Rs 3500), collateral must be about Rs 4000–5000 on average. The rewards offered in the large-magnitude experiments were as much as 10% of this. If the elasticity of substitution between consumption in different periods is fairly low, the relaxation of the borrowing constraint implied by a 10% increase in collateral could result in a substantial reduction in the marginal rate of substitution and the discount rate.

We have seen that Model 3 may explain observed time frame and magnitude effects. Model 2 also can explain the time frame effect for similar reasons. Since borrowers face an upward-sloping supply curve for credit in this model, they will not wish to perfectly smooth consumption through borrowing, thus contributing to consumption seasonality. Model 2 does not predict the magnitude effect, since the effect of future wealth on borrowing and discount rates is generally ambiguous, though it is not necessarily inconsistent with this effect.

5.2.2. Wealth effects

The inverse relationship between current wealth and discount rates is consistent with both Models 2 and 3. In both of these models, there is a tendency for discount rates to fall with increases in current wealth because the demand for credit falls as wealth increases, eventually causing individuals to become lenders at high enough levels of wealth.

An alternative explanation that may occur to the reader for the inverse relationship between current wealth and discount rates is that of reverse causality: individuals with lower discount rates will save and accumulate more wealth over time. While this explanation sounds plausible, it is important to recognize that the discount rate as measured in this study is not an underlying preference parameter that necessarily stays constant over time. Rather, it is a measure of the marginal rate of intertemporal substitution between two specified future dates, and as such reflects expectations about wealth at those dates and the possibilities for consump-

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37 Anecdotal evidence suggests that most villagers were well aware of the study and the rewards offered, since many non-respondents expressed their desire to participate in the follow-up study in 1991.
tion smoothing, as the discussion in section 2 makes clear. Thus it is appropriate to view wealth at the time of the experiment as a predetermined variable, and the discount rate as an outcome variable. In addition, as noted in section 3, econometric tests provide no support for the hypothesis that wealth is an endogenous variable in the discount rate regressions.

Horowitz also found evidence of an inverse relationship between discount rates and wealth. He argued that this relationship might arise because wealthier individuals may face lower borrowing costs or have a greater understanding of finance. The first explanation is similar to the predictions of Model 2. The latter assertion is plausible, though it is not clear why an inadequate understanding of finance would lead to an upward bias in discount rates. I do control for the age and level of education of the respondents, but there may be unobserved differences in abilities or financial sophistication that are correlated with wealth. Thus, we cannot rule out this explanation entirely.

Hausman (1979) estimated individual discount rates of a sample of households in the United States based upon their purchases and utilization of durable goods of different energy efficiencies. He found a significant negative relationship between household income and estimated discount rates. Possible explanations he suggested for this included progressive income tax rates, limited availability of credit to poorer households, and greater uncertainty in their income streams. The first explanation would not apply to the respondents in the present study, since they do not pay income taxes. The third explanation would not explain variations in discount rates based upon certain rewards offered at different dates, as shown for Model 1. The nature of credit markets appears to be an important part of the explanation for observed discount rates in the study villages.

Although the discount rate study clearly rejects Model 1, it is difficult to distinguish between Model 2 and Model 3 using the discount rate data alone, since both models could be consistent with these data. Analysis of the credit market data leads to mixed results. The fact that borrowing increases with wealth for low levels of wealth (and declines at high levels of wealth) contradicts Model 2 and is consistent with Model 3. But the fact that the maximum interest rate on debt also increases with wealth at low levels of wealth and declines at high levels of wealth contradicts both models.

These results suggest a model combining Models 2 and 3, in which borrowers face an upward-sloping supply curve for credit up to a maximum level of credit

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38 The same assumption is made in all dynamic models of household consumption, in which current wealth is a predetermined state variable that determines subsequent choices regarding consumption (and hence intertemporal substitution).

39 In the present study, a few respondents exhibited negative discount rates, despite obvious opportunities to save at positive real interest rates (for example, by accumulating silver). It is difficult to explain this other than as a result of these respondents' inadequate understanding of their financial opportunities or of the experiment.
determined by an enforcement constraint\(^40\). This may be the case if lenders are uncertain about the borrowers’ valuation of the penalty that can be assessed in the event of default\(^41\). If the maximum penalty lenders expect to be able to inflict is an increasing function of wealth, borrowers with little wealth may face a binding enforcement constraint, and as wealth increases, more borrowing is allowed but at a higher interest rate. This process continues until the enforcement constraint is no longer binding. Beyond this point, increases in wealth cause the borrower to move back down the credit supply curve as his nominal demand for credit falls.

This model is similar to that proposed by Bell, Srinivasan, and Udry to explain the interaction of formal and informal lending in rural Punjab, except that their model assumes that credit constraints bind only in the formal sector. That model would not explain the results of this study, since it implies that marginal interest rates paid on debt will not increase as wealth increases and notional credit demand falls. The presence of binding credit constraints in the informal sector appears necessary to explain the results of this study\(^42\).

6. Conclusions

The high discount rates measured in this study imply a rational disregard by most households in the study villages for all but very near term impacts of decisions. Given that real interest rates of 30% are commonly charged by moneylenders in the villages, such a finding is not unexpected. What is more remarkable, perhaps, is how little attention has been paid to the nature of credit markets in the literature on sustainable development. Efforts to preserve forest areas or to promote adoption of soil and water conservation technologies may have little success in areas where poverty and limited development of credit markets lead to such high discount rates.

The presence of binding credit constraints implies that different households have different marginal products of capital and marginal rates of intertemporal substitution, resulting in inefficient allocation of resources. It also suggests a tendency towards persistent inequality, since wealthier households will be able to take advantage of investment opportunities that poorer households will rationally forego due to their higher discount rate.

Government policies to regulate interest rates and to provide subsidized credit likely exacerbate rather than remedy the problems associated with credit rationing. Such policies may inhibit the development of the financial system and contribute to tight rationing of formal sector credit. In addition, they can reduce the viability

\(^{40}\) This possibility has been suggested by Bell (1988) (p. 778).

\(^{41}\) Benjamin’s model of credit constraints, discussed briefly in footnote 11, has the properties suggested here.

\(^{42}\) Interestingly, Bell, Srinivasan, and Udry found that the supply of informal credit was highly interest inelastic, which may be due to binding credit constraints.
of informal sector lenders by undermining their ability to enforce credit contracts, possibly leaving many borrowers with fewer and more expensive sources of credit. For example, large moneylenders have largely disappeared since expansion of formal sector credit began in the 1950s in four Maharashtra villages studied by Binswanger et al., and the moneylenders that remain "tend to lend smaller amounts per loan for shorter duration, and at higher interest rates". A better approach would be to focus upon the causes of credit constraints, including interest rate regulations and subsidies in the formal market, and the need for collateral substitutes in the informal market. Innovations such as group lending with peer monitoring and joint liability, such as the well-publicized example of the Grameen Bank in Bangladesh, may serve as effective collateral substitutes and thus help to relax credit constraints.

In the long run, broad-based economic development, including development of credit markets, is the most certain way to relax credit constraints and increase the extent to which households in developing countries consider the future in their decisions. Economic development may thus be a prerequisite, rather than a competing objective, to the goal of sustainable resource use.

Acknowledgements

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Appendix A. Derivation of the discount rate and comparative statics of Model 2

Assume that the equilibrium in the model is such that the probability of default is in (0,1). Denote the competitive interest rate by \( r(B,z) \), where \( \partial r/\partial B > 0 \) and \( \partial r/\partial z < 0 \). Define the minimum level of \( v \) for the borrower to repay the loan:

\[
u_{\text{min}} = (1 + r)B + c_{\text{min}} - z \tag{A.1}\]

The borrower's problem is to:

\[
\max_B u_1(w + B) + \text{Prob}(v < v_{\text{min}})u_2(c_{\text{min}}) + \int_{v_{\text{min}}}^{b} u_2(z + v - (1 + r)B)f(v)\,dv \tag{A.2}\]

\[43\] The Indian government has deregulated the formal financial sector since 1991.
Differentiation with respect to $B$ yields the first-order condition:

$$U_B = u'_1(c_1) - \left(1 + r + B \frac{\partial r}{\partial B}\right) \int_{v_{\min}}^{b} u'_2(c_2) f(v) dv = 0$$  \hspace{1cm} (A.3)

The first-order condition implies that:

$$1 + r + B \frac{\partial r}{\partial B} = - \frac{u'_1(c_1)}{\int_{v_{\min}}^{b} u'_2(z + v - (1 + r) B) f(v) dv}$$  \hspace{1cm} (A.4)

Defining $V(w, z)$ as the indirect utility function for (A.2), using the envelope theorem one can show that:

$$\frac{\partial V}{\partial w} = \frac{u'_1(c_1)}{\left(1 - B \frac{\partial r}{\partial z}\right)} \int_{v_{\min}}^{b} u'_2(z + v - (1 + r) B) f(v) dv$$  \hspace{1cm} (A.5)

Eq. (6) is obtained by substituting (A.4) into (A.5).

The effect on borrowing of an increase in current wealth is determined by totally differentiating the first-order condition and rearranging terms:

$$\frac{dB}{d\omega} = - \frac{u'_1(c_1)}{U_{BB}} < 0$$  \hspace{1cm} (A.6)

since $U_{BB} < 0$ to satisfy the second-order condition.

The effect of an increase in future income on borrowing is ambiguous in general. Differentiating $U_B$ with respect to $z$, we obtain:

$$U_{Bz} = - \left(\frac{\partial r}{\partial z} + B \frac{\partial^2 r}{\partial B \partial z}\right) \int_{v_{\min}}^{b} u'_2(c_2) f(v) dv - \left(1 + r + B \frac{\partial r}{\partial B}\right)$$

$$\times \left[- \frac{\partial v_{\min}}{\partial z} u'_2(c_{\min}) f(v_{\min}) + \int_{v_{\min}}^{b} u'_2(c_2) f(v) dv\right]$$  \hspace{1cm} (A.7)

From Eq. (A.1):

$$\frac{\partial v_{\min}}{\partial z} = -1$$  \hspace{1cm} (A.8)

This fact, together with the facts that $u'_1 > 0$ and $u'_2 < 0$, implies that $U_{Bz}$ is ambiguous in sign, even if the sign of $\partial^2 r/\partial B \partial z$ could be determined. This implies that $dB/dz$ is ambiguous.

**Appendix B. The experiments**

Below are the choices offered in the experiments (the continuous time discount rate implied if the respondent is indifferent is given in parentheses).
G1:
1. 10 kg in September 1989 or 9 kg in April 1990 (−18%)
2. 10 kg in September 1989 or 10 kg in April 1990 (0%)
3. 10 kg in September 1989 or 11 kg in April 1990 (16)
4. 10 kg in September 1989 or 12 kg in April 1990 (31)
5. 10 kg in September 1989 or 13 kg in April 1990 (45)
6. 10 kg in September 1989 or 15 kg in April 1990 (70)
7. 10 kg in September 1989 or 17 kg in April 1990 (91)
8. 10 kg in September 1989 or 20 kg in April 1990 (119)

G2:
1. 10 kg in September 1989 or 9 kg in September 1990 (−11%)
2. 10 kg in September 1989 or 10 kg in September 1990 (0%)
3. 10 kg in September 1989 or 11 kg in September 1990 (10)
4. 10 kg in September 1989 or 12 kg in September 1990 (18)
5. 10 kg in September 1989 or 13 kg in September 1990 (26)
6. 10 kg in September 1989 or 15 kg in September 1990 (41)
7. 10 kg in September 1989 or 17 kg in September 1990 (53)
8. 10 kg in September 1989 or 20 kg in September 1990 (69)

G3:
1. 50 kg in September 1989 or 45 kg in September 1990 (−11%)
2. 50 kg in September 1989 or 50 kg in September 1990 (0%)
3. 50 kg in September 1989 or 52 kg in September 1990 (4)
4. 50 kg in September 1989 or 54 kg in September 1990 (8)
5. 50 kg in September 1989 or 57 kg in September 1990 (13)
6. 50 kg in September 1989 or 60 kg in September 1990 (18)
7. 50 kg in September 1989 or 65 kg in September 1990 (26)
8. 50 kg in September 1989 or 70 kg in September 1990 (34)
9. 50 kg in September 1989 or 80 kg in September 1990 (47)
10. 50 kg in September 1989 or 100 kg in September 1990 (69)

G4:
1. 14 kg in April 1990 or 7 kg in September 1989 (119%)
2. 14 kg in April 1990 or 8 kg in September 1989 (96)
3. 14 kg in April 1990 or 9 kg in September 1989 (76)
4. 14 kg in April 1990 or 10 kg in September 1989 (58)
5. 14 kg in April 1990 or 11 kg in September 1989 (41)
6. 14 kg in April 1990 or 12 kg in September 1989 (26)
7. 14 kg in April 1990 or 13 kg in September 1989 (13)
8. 14 kg in April 1990 or 14 kg in September 1989 (0)
9. 14 kg in April 1990 or 15 kg in September 1989 (−12)

G5:
1. 14 kg in September 1990 or 7 kg in September 1989 (69%)
2. 14 kg in September 1990 or 8 kg in September 1989 (56)
3. 14 kg in September 1990 or 9 kg in September 1989 (44)
4. 14 kg in September 1990 or 10 kg in September 1989 (34)
5. 14 kg in September 1990 or 11 kg in September 1989 (24)
6. 14 kg in September 1990 or 12 kg in September 1989 (15)
7. 14 kg in September 1990 or 13 kg in September 1989 (7)
8. 14 kg in September 1990 or 14 kg in September 1989 (0)
9. 14 kg in September 1990 or 15 kg in September 1989 (−7)

G6:
1. 65 kg in September 1990 or 35 kg in September 1989 (62%)
2. 65 kg in September 1990 or 40 kg in September 1989 (49)
3. 65 kg in September 1990 or 45 kg in September 1989 (37)
4. 65 kg in September 1990 or 50 kg in September 1989 (26)
5. 65 kg in September 1990 or 54 kg in September 1989 (19)
6. 65 kg in September 1990 or 57 kg in September 1989 (13)
7. 65 kg in September 1990 or 60 kg in September 1989 (8)
8. 65 kg in September 1990 or 63 kg in September 1989 (3)
9. 65 kg in September 1990 or 65 kg in September 1989 (0)
10. 65 kg in September 1990 or 70 kg in September 1989 (−7)

H1:
1. 10 kg in September 1991 or 10 kg in April 1992 (0%)
2. 10 kg in September 1991 or 11 kg in April 1992 (16)
3. 10 kg in September 1991 or 12 kg in April 1992 (31)
4. 10 kg in September 1991 or 13 kg in April 1992 (45)
5. 10 kg in September 1991 or 14 kg in April 1992 (58)
6. 10 kg in September 1991 or 15 kg in April 1992 (69)
7. 10 kg in September 1991 or 17 kg in April 1992 (91)
8. 10 kg in September 1991 or 20 kg in April 1992 (119)

H2:
1. 10 kg in September 1991 or 10 kg in September 1992 (0%)
2. 10 kg in September 1991 or 11 kg in September 1992 (9)
3. 10 kg in September 1991 or 12 kg in September 1992 (18)
4. 10 kg in September 1991 or 13 kg in September 1992 (26)
5. 10 kg in September 1991 or 14 kg in September 1992 (34)
6. 10 kg in September 1991 or 15 kg in September 1992 (41)
7. 10 kg in September 1991 or 16 kg in September 1992 (47)
8. 10 kg in September 1991 or 17 kg in September 1992 (53)
9. 10 kg in September 1991 or 18 kg in September 1992 (59)
10. 10 kg in September 1991 or 20 kg in September 1992 (69)

H3:
1. 10 kg in September 1991 or 10 kg in April 1993 (0%)
2. 10 kg in September 1991 or 12 kg in April 1993 (11)
3. 10 kg in September 1991 or 13 kg in April 1993 (17)
4. 10 kg in September 1991 or 15 kg in April 1993 (26)
5. 10 kg in September 1991 or 17 kg in April 1993 (34)
6. 10 kg in September 1991 or 19 kg in April 1993 (41)
7. 10 kg in September 1991 or 21 kg in April 1993 (47)
8. 10 kg in September 1991 or 23 kg in April 1993 (53)
9. 10 kg in September 1991 or 25 kg in April 1993 (58)
10. 10 kg in September 1991 or 30 kg in April 1993 (69)

H4:
1. 10 kg in September 1991 or 10 kg in September 1993 (0%)
2. 10 kg in September 1991 or 12 kg in September 1993 (9)
3. 10 kg in September 1991 or 14 kg in September 1993 (17)
4. 10 kg in September 1991 or 17 kg in September 1993 (26)
5. 10 kg in September 1991 or 20 kg in September 1993 (34)
6. 10 kg in September 1991 or 24 kg in September 1993 (42)
7. 10 kg in September 1991 or 26 kg in September 1993 (48)
8. 10 kg in September 1991 or 29 kg in September 1993 (53)
9. 10 kg in September 1991 or 32 kg in September 1993 (58)
10. 10 kg in September 1991 or 40 kg in September 1993 (69)

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