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Borrowing Requirements, Credit Access, and Adverse Selection: Evidence from Kenya
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ABSTRACT

We examine the potential of asset-collateralized loans in low-income country credit markets. When a Kenyan dairy cooperative exogenously replaced high down payments and joint liability requirements with loans collateralized by the asset itself - a large water tank- loan take-up increased from 2.4%to 41.9%. In contrast, substituting joint liability requirements for deposit requirements had no impact on loan take up. There were no repossessions among farmers allowed to collateralize 75% of their loans, and a 0.7% repossession rate among those offered 96% asset collateralization. A Karlan-Zinman test based on waiving borrowing requirements ex post finds evidence of adverse selection with very low deposit requirements, but not of moral hazard. A simple model and rough calibration suggests that adverse selection and regulatory caps on interest rates may deter lenders from making welfare-improving loans with low deposit requirements. We estimate that 2/3 of marginal loans led to increased water storage investment. Real effects of loosening borrowing requirements include increased household water access, reductions in child time spent on water-related tasks, and greater school enrollment for girls.

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1 Introduction

Formal credit markets are typically much less developed in low-income than high-income countries (Rajan and Zingales, 1998; La Porta et al., 1997, World Bank, 2014). Weak legal institutions, difficulties in contract enforcement, and regulatory caps on interest rates can all induce lenders to impose very restrictive borrowing conditions.

In this lending environment, a large literature in development economics examines the potential for microfinance to expand access to credit, often through joint liability lending (Morduch, 1999; Hermes and Lensink, 2007). However, results are often underwhelming. For example, Banerjee et al. (2015) review RCTs on six microfinance programs, finding both limited evidence of impacts on investment and limited uptake of these programs. In contrast, the types of asset-collateralized loans that are mainstays of lending in the developed world have received much less attention. While U.S. consumers can obtain car loans or mortgages relatively easily, for example, these are much rarer in poor countries, and when they are available, borrowers typically must make large down payments.

To assess the potential of asset-collateralized loans, we examine whether potential borrowers react differently when restrictive lending conditions with high down payments and/or equivalent joint liability requirements are exogenously replaced with loans that are instead collateralized by the asset itself. Specifically, the lender is a Kenyan savings cooperative which offered farmers loans to for the purchase of large rainwater harvesting tanks (the asset), with exogenously varying requirements.

We examine how demand for credit and subsequent repayment behavior is affected when asset collateralization replaces high deposits or joint liability requirements. To measure the extent to which loosening borrowing requirements generates either adverse selection or moral hazard, we use *ex post* waivers of borrowing requirements (as in Karlan and Zinman, 2009). Finally, we test whether loosening borrowing requirements has real effects on investment.

We find that allowing borrowers to collateralize loans using assets purchased with the loans dramatically increased borrowing. Only 2.4% of farmers borrowed under the savings cooperative's standard borrowing conditions, which require that one third of the loan be secured with deposits by the borrower, and that the remaining two thirds be secured with cash or shares from guarantors. The loan take up rate increased to 23.9% when 75% of the loan could be collateralized with the tank itself and the remaining 25% collateralized with a deposit. The take-up rate further increased to 41.9% when all but 4% of the loan could be collateralized with the tank. Thus more than 90% of those who wished to borrow at the available interest rate were credit-constrained.[1] Results were similar both in the initial set of loans, and in a separate out-of-sample test.

We also find no evidence that joint liability expands credit access. There was no statistically significant difference in loan take up between farmers offered loans with a 25 percent deposit requirement and those offered the opportunity to substitute guarantors for all but 4 percent of the loan value.

With regards to repayment, we find that loosening borrowing requirements from their initial draconian levels to moderate levels did not lead to tank repossession, but there was evidence of adverse selection when borrowing requirements became sufficiently weak. There were no tank repossessions with 25% deposit or guarantor requirements. Reducing the deposit to 4% induced a 0.7% repossession rate overall, corresponding to a 1.63% repossession rate among the marginal farmers induced to borrow by the lower borrowing requirements. The hypothesis of equal rates of tank repossession rates under a 4% deposit requirement and under a 25% deposit or guarantor requirement is rejected at the 5.25% level using a Fisher exact test. Karlan-Zinman tests based on *ex post* waivers or borrowing requirements suggest this difference is entirely due to selection, rather than treatment effects. Stricter borrowing requirements also reduced the number of borrowers who ever made late payments, and there is evidence (significant at the 7% level), of selection effects on this margin as well.

A simple model suggests that under adverse selection, profit maximizing deposit rates will exceed socially optimal deposit rates. To see the intuition for a monopolistic lender, note that at the margin, raising deposit requirements selects out unprofitable borrowers but imposes a cost on credit-constrained inframarginal borrowers, and a profit-maximizing lender will not internalize these costs to inframarginal borrowers. A rough calibration of the model suggests that while average rates of tank repossession were low, moving from a 25% to a 4% deposit requirement induces one marginal tank repossession for every 62 additional borrowers. Repossession costs are large enough that this would not be profitable for the lender. However, we estimate that if farmers have investment opportunities yielding even very modest rates of return, the lower borrowing requirement would have increased welfare among inframarginal borrowers by more than it would reduce profits. Consistent with the results of the calibration, after learning the results of the program, the lender changed its policy to allow 75% collateralization with the tank, but not to allow 96% collateralization.

Finally, with regards to investments, we find that those offered the opportunity to collateralize

[1] If potential borrowers have investments that yield a higher rate of return than that paid by the lender on deposits, tying up funds in a deposit will be costly and loan take up rates will be sensitive to deposit requirements. In contrast, if potential borrowers lack good investment opportunities or already have access to finance through informal financial markets, then they will not respond to relaxed borrowing constraints.

loans with the tanks had more water storage capacity and were more likely to have purchased large rainwater harvesting tanks. These results also suggest that improving credit access can influence technology adoption (Zeller et al., 1998). Consistent with Devoto et al. (2013), our results suggest that credit provision can contribute to increasing access to clean water in the developing world. Children of households offered less restrictive credit terms spent somewhat less time collecting water and tending livestock and difference-in-difference estimates find that fewer girls in these households were out of school. Our sample size, and hence statistical power, is too limited to rule out either no impact or a large impact on milk production.

The rest of the paper is organized as follows: Section two provides background on small-holder dairy farming in the region we study. Section three presents a model with which we interpret the data. Section four explains the program design. Section five explains the data and our empirical specifications. Section six discusses the impact of borrowing requirements on loan take up and on borrower characteristics. Section seven discusses the treatment, selection, and overall impacts of relaxing borrowing conditions on loan recovery, tank repossession, and late payment, and calibrates the model to the data. Section eight discusses the impacts on real outcomes. Section nine concludes by discussing potential policy implications and directions for further research, including the possible role of prospect theory in accounting for results on borrower behavior.

2 Background

We examine the potential of asset-collateralized credit using loans for large rainwater harvesting tanks among a population of dairy farmers in an area straddling Kenya's Central and Rift Valley provinces. Because installation of water supply at the household level requires substantial fixed costs, there has been increasing interest in whether extension of credit can help improve access to water (Devoto et al 2011).[2]

In the area we examine, approximately 30% of farmers are connected to piped water systems, but these systems provide water only intermittently, typically three days per week. 70% of farmers do not have any connection to a water system. They are not alone. WHO and UNICEF estimate that approximately 900 million people lack access to water at their homes (2010), with substantial consequences for global health and human development.

Collection of water from distant sources limits water use, including for hand washing and cleaning, with potential negative health consequences (Wang and Hunter, 2010; Esrey 1996). It also imposes a substantial time burden, particularly for women and girls, with potentially

[2]See also http://www.waterforpeople.org/.

negative consequences for schooling.[3] Devoto (2013) finds that provision of household water connections leads to lower levels of intra- and inter- family conflict and higher well-being, even in the absence of health and income gains.

Dairy farmers in particular benefit from reliable access to water because dairy cattle require a regular water supply (Nicholson (1987), Peden et al. (2007), and Staal et al (2001)). In the relatively high rainfall area we study, rainwater harvesting systems can meet a substantial portion of water needs for smallholder dairy farmers. Without easy access to water, the most common means of watering cattle is to take them to a source every two or three days, which is time consuming and can expose cattle to disease (Kristjanson et al. 1999).[4]

Rainwater harvesting tanks provide convenient access to water, reducing the need to travel to collect water and then carry it home. Moreover, rainwater is not subject to contamination by disease-bearing fecal matter. Historically, many farmers in the area used stone or metal tanks to harvest rainwater or store piped water for days when piped water is not available. Approximately one-quarter of comparison group farmers had a water storage tank of more than 2,500-liter capacity at baseline. However, stone tanks are susceptible to cracking, and metal tanks are susceptible to rusting, so neither approach is particularly durable. Lightweight, durable plastic rainwater harvesting tanks were introduced about 10 years ago. These plastic rainwater harvesting tanks are displayed prominently at agricultural supply dealers in the area and are the dominant choice for farmers obtaining new tanks, so they are not an unfamiliar concept to farmers, but they cost about $320 or 20% of household consumption, so few farmers own them.

Like many of Kenya's approximately one million smallholder dairy farmers, the farmers in our study sell milk to a dairy cooperative, the Nyala dairy cooperative (although not all are members of the cooperative). The Nyala dairy cooperative performs basic quality tests, cools the milk, and then sells it to a large-scale milk producer for pasteurization and sale to the national market. It keeps track of milk deliveries and pays farmers monthly. During the time period we study, selling to the Nyala dairy was more lucrative for farmers than selling on the local market or to another dairy, which would have involved higher transport costs.[5]

The Nyala dairy cooperative has an associated savings and credit association (SACCO). These are widespread in Kenya, with total membership of almost five percent of the population.[6] SAC-

[3]In our baseline survey, women report spending 21 minutes per day fetching water, three times as much as men, and our enumerators reported that women were typically more eager than their husbands to purchase tanks.

[4]During the baseline survey, it was reported that farmers spent on average ten hours per week taking their cows to the water sources.

[5]Casaburi and Macchiavello (2014) examine a different Kenyan context in which farmers sell to dairies even though the dairy pays a lower price than the local market, arguing that farmers value the savings opportunity generated by the monthly, rather than daily, payments provided by dairies.

[6]Until 2012, many dairy cooperatives ran SACCOs as a service to their members, with the dairy cooperative's management also overseeing the SACCO. The 2012 SACCO act made cooperatives separate farming and banking activi-

COs are typically limited to a 12% annual interest rate, but in some cases they can charge 14% annually (SASRA, 2013). (In practice, this is interpreted as 1% monthly interest and 1.2% monthly interest.) Perhaps as a result, SACCOs are typically conservative in their lending, imposing stringent borrowing requirements.

In the SACCO we examine, the borrower must have savings deposited in the SACCO worth 1/3 of the total amount of the loan and must find up to three guarantors willing to collateralize the remaining 2/3 of the loan with savings and/or shares in the cooperative. Borrowers and guarantors are paid the same standard 3% quarterly interest on funds deposited in the SACCO as are other depositors. The Nyala SACCO offers loans for a variety of purposes, mostly school fees and emergency loans in the case of illness and agricultural loans in kind (advances on feed). In the year prior to the study, it made just 292 cash loans to members, averaging KSh 25,000 ($315).

In order to examine how potential borrowers respond to different potential loan contracts, we focus on an environment in which lending is feasible. Several features of the institutional environment are favorable to lending. First, farmers who borrow agree to let the SACCO deduct loan repayments from the dairy's payments to the farmer for milk. This provides a very easy mechanism for collecting debt that not only has low administrative cost for the lender but also effectively makes repayment the default option for borrowers, instead of requiring them to actively take steps to repay debt. Second, the dairy paid a higher price for milk than alternative buyers, providing farmers with an incentive to maintain their relationship with the dairy. Finally, the SACCO may have more legitimacy in collecting debt than would an outside for-profit lender.

The physical characteristics of rainwater harvesting tanks also make them well-suited as collateral. The tanks are bulky and have to be installed next to the user's house, so a lender seeking to repossess a tank can find them easily. Moreover, tanks have no moving parts and are durable, so they preserve much of their value through the repossession and resale process. Finally, while tanks are too large for borrowers to easily transport by hand more than a short distance, a lender seeking to repossess them can easily load them onto a truck.

ties. SACCOs previously run by a dairy cooperative became a separate legal entity but have tended to retain strong links with the dairy cooperative.

3 Model[7]

In order to help motivate the empirical work in subsequent sections, we present a simple model following Stiglitz and Weiss (1981) in which strict borrowing requirements can potentially both address moral hazard by incentivizing borrowers to repay and respond to adverse selection by selecting more profitable borrowers. We first lay out our assumptions in Section 3.1. In section 3.2, we consider the farmer's problem and show that higher deposit requirements will reduce loan take up if and only if farmers are credit constrained. In section 3.3, we present the lender's problem and show our main result - that if strict deposit requirements select more profitable marginal borrowers, lenders will generically choose stricter deposit requirements than would be socially optimal.

3.1 Assumptions

We consider an economy with a monopoly lender, which has cost of capital R_D.[8] The lender chooses a required deposit value D^* to maximize expected profits. R is the gross interest rate charged to borrowers, so borrowers must repay RC in total to the lender at the end of the contract, where C is the cost of a tank. (Empirically, R corresponds to the 1% per month interest rate charged by the SACCO.)

There is a continuum of farmers, with water tank valuation continuously distributed over the interval $[\underline{\theta}, \bar{\theta}]$ according to some (non-degenerate) cumulative distribution function $F(\theta)$. The distribution has positive density throughout its support and has no mass points. $\bar{\theta} > RC > \underline{\theta} > 0$, so some farmers are not willing to purchase tanks at full cost, but every farmer would purchase a tank if it were free. Farmer i's valuation of the tank is denoted θ_i. θ_i is private information encompassing utility benefits of the tank, time savings, and any dairy farming productivity benefits. Farmers value consumption of a composite good as well as water tanks. Farmers have an initial wealth w at period $t = 1$ and future stochastic income at period $t = 2$ denoted y_i and drawn from $\left[\underline{Y}, \bar{Y}\right]$ according to distribution $F_Y(\cdot)$. (In our actual context, farmers are subject to considerable income uncertainty, and can even have negative income realizations, for example if a cow dies.) Farmers can purchase tanks in period $t = 1$ through a contract with the lender. If they purchase a tank, then in period $t = 2$ they choose whether to repay the loan or allow the tank to be repossessed. If farmers borrow to buy a tank, they must make a deposit D, which earns interest rate R_D. Whether or not they buy a tank, they can also save in the SACCO (or in another SACCO or a commercial bank) at rate R_D. Farmers have alternate uses of funds

[7]We thank Egor Abramov, William Glennerster, Itzchak Raz, and Kevin Xie for their help on this section.

[8]The SACCO may have a small amount of capital available at very low cost from its earnings from transaction fees on payments to farmers, but we will treat its cost of capital at the margin as the 3% per quarter it pays to depositors.

that generate gross returns R_B, if held until period 3. However, if these alternative investments are liquidated early, we will assume only the principal is preserved, and the return $R_B - 1$ is not realized. If the expected return on the alternative investment is less than R_D, farmer's best investment will be to hold their assets in the SACCO.

We assume that $\bar{Y} > RC$, so that farmers with favorable enough income realizations have sufficient funds to pay back the principal and interest on tank loans, and that $\underline{Y} < (R-1)C$, so that farmers with low enough income realizations do not have sufficient funds in order to repay tank loans unless they liquidate other assets. We assume that w is large enough so that loan repayment is always feasible.[9]

We focus on the case in which the expected return from the alternative investment, taking into account the probability that this investment may need to be liquidated, is greater than that from holding funds in the SACCO. This makes holding wealth in the SACCO costly and is thus consistent with our empirical result that greater deposit requirements reduce loan take up dramatically. In particular, we assume that $(1 - F_Y(RC))R_B + F_Y(RC) > R_D$.

There is a limited liability constraint so that if the borrower fails to repay, the only assets which can be seized are the pledged deposit and the tank. The lender incurs an expected total cost $K \geq 0$ to repossess a tank (e.g., rental costs for a truck to move the tank, the time of staff members and the security guard who is present at repossessions, management time, the risk of negative publicity or vandalism by a disgruntled borrower). If the tank is repossessed, it is sold for δC, where $\delta \leq 1$,[10] and the lender is repaid the principal, interest, and late fees, as well as a repossession fee. Any remaining proceeds from the sale go to the borrower. Denote the repossession fee charged to the borrower as $K_B < K$. (In the program we examine, farmers were charged a KSh 4,000 repossession fee, but we estimate the full cost of repossession at KSh 8,500, even excluding intangible costs like the costs of bad publicity and the risk of vandalism.)[11]

The distributions of water tank valuation and income are independent and have positive densities throughout their supports, and $\bar{\theta} > R_B C$, so the highest-valuation farmers are willing to give up $R_B C$ in returns on the outside investment to obtain a tank.

[9] Farmers also own land, and while land markets are thin and transaction costs for formal sales are high, some sales and rental transactions do take place. (For a discussion of land tenure, see Place and Migot-Adholla, 1998; Barrows and Roth 1990).

[10] The assumption that $\delta \leq 1$ is natural in the case of a scaled-up permanent program, but because tanks were made available at the wholesale price under the program we examine, and because the program was available to only some farmers, the resale value of a repossessed tank could potentially be somewhat greater than C in our context, and indeed one repossessed tank sold for more than the wholesale price.

[11] Our model abstracts from risk aversion, but if farmers are risk averse, it will generally not be optimal for borrowers to fully bear the risk associated with negative income shocks that lead to tank repossession. Beyond this, one could imagine that if the contract imposed severe penalties on borrowers during periods when they had negative income shocks and had to allow tank repossession, some borrowers might react in ways that would create large costs for the SACCO, for example vandalizing tanks prior to repossession.

There are three periods:

1. At period $t = 1$, the lender chooses the required deposit D, and potential borrowers decide whether or not to take the loan and make decisions regarding alternative investments.
2. At period $t = 2$ farmer income y_i is realized and the loan is to be repaid. Farmers with low realizations of income can either allow the tank to be repossessed, thus losing the tank but getting the proceedings from the tank sale minus the deductions for the amount owed to the lender and the repossession penalty, K_B, or they can liquidate a portion of their other investments at the cost of losing the net returns $R_B - 1$ on the liquidated investments. If borrowers use their deposits in the SACCO to repay the loans, they earn interest R_D which is paid in period 3.[12] Farmers will therefore liquidate alternative investments only as a last resort after using up any funds in the SACCO.
3. Farmers who repay their loans receive net interest on deposits, $(R_D - 1)D$, if they did not allow repossession. To keep notation simple, we will assume that utility from consumption of the tank and of other goods is realized in period 3.

Below, we first solve the farmer's problem of whether to borrow and whether to repay given the D chosen by the lender. We then solve for the first order conditions for the profit maximizing D^* for the lender, and show how conditions for profit maximization will differ from conditions for a social optimum.

3.2 The Farmers' Problem

Given the deposit requirement, farmers face two decisions: whether to take out a loan, and whether to repay the loan, if necessary by liquidating a portion of their other assets and giving up the return on those assets, or alternatively to allow the tank to be repossessed. We solve backwards, working from the decision of whether to repay the loan or to allow tank repossession.

Proposition 1. *Conditional on having taken out a loan and an income realization y_i, a farmer will repay the loan if and only if the farmer's tank valuation, θ, is greater than a repayment threshold, $\theta^R(y_i, D)$, where θ^R is decreasing in D and is non-increasing in y.*

Proof : see appendix.

θ^R defines a repayment probability that is increasing in D.

[12]The SACCO pays interest every quarter, so farmers could lose some interest through early liquidation, but any losses will be small so we treat them as negligible in the model.

Note that some farmers will allow tanks to be repossessed even if this is not socially optimal, because the lender incurs some of the cost of repossession, since K_B, the penalty for tank repossession, is less than K. Moreover, the farmer will have negative equity if $R_D D$ plus the resale value of the tank δC is less than $RC + K_B$. (As will become clear below, this further implies that farmers may borrow to buy a tank even if θ_i, the value of the tank, does not exceed $RC + F_Y(Y^R)K$, the cost of paying back the loan plus the expected social cost of default). A greater deposit could potentially ameliorate the moral hazard problem and reduce tank repossession.

Having solved for repayment behavior conditional on borrowing, we can now solve for borrowing behavior.

Proposition 2. *Farmers will borrow if $\theta_i > \theta^*(D)$, where θ^* is increasing in D. Hence, the repossession rate will be:*

$$\int_{\theta^*(D)}^{\bar{\theta}} F_Y(Y^R(\theta, D))dF_\theta(s), \tag{1}$$

and this repossession rate will be decreasing in the deposit rate D.

Proof: See Appendix.

Given the assumptions on the support of the cumulative distribution function $F(\theta_i)$ a marginal farmer exists, denoted by $\theta^*(D) < \bar{\theta}$, who is indifferent whether to borrow. Farmers with greater valuations will borrow while farmers with lower valuations will not. Thus, the mass of farmers who borrow is given by $1 - F(\theta^*(D))$.

Proposition 3. *If $(1 - F_Y(RC))R_B + F_Y(RC) > R_D$, farmers with $\theta_i > \theta^*(D)$ are strictly better off with a lower deposit, and those with $\theta_i < \theta^*(D)$ are indifferent to marginal changes in D. If farmers are not credit constrained - that is, $R_B \leq R_D$ - then the deposit requirement does not affect the decision of whether to borrow.*

Proof: see appendix.

To see the first part of the proposition, note that farmers who do borrow would prefer to have a lower deposit and thus to be able to take advantage of the other investment opportunity which has a higher return. Farmers who do not borrow are indifferent to marginal changes in the deposit. A finding that a farmer would be willing to borrow under a low deposit requirement but not a higher deposit requirement implies that the farmer has better investment opportunities than holding assets as deposits in the SACCO, and thus that a higher deposit requirement is costly for the farmer.

To see the second result, that under the alternative assumption, $R_B \leq R_D$, the loan take-up decision of borrowers who repay their loans will not be affected by the deposit requirement, note that if $R_B \leq R_D$, farmers will invest in SACCO deposits even in the absence of borrowing requirements.

3.3 The Lender's Problem

Now consider a profit-maximizing lender's problem of choosing the optimal deposit D^*. The lender earns a net profit

$$P_{loan}(D) = P_{loan} = (R - R_D)C \tag{2}$$

per customer who repays without a tank repossession, equal to the interest paid by the borrower minus the cost of borrowing the capital to finance the loan, $R_D C$.

To calculate the payoff to the lender when a borrower fails to repay a loan and the tank has to be repossessed, note that the lender will seize the deposit and the accrued interest, $R_D D$, sell the repossessed tank for δC, and incur the cost of repossession, K, in addition to the previous outlay on borrowing the capital for the loan, $R_D C$. It will obtain δC from selling the tank, but will have to return to the borrower any proceeds of the tank sale net of interest and repossession fees, $max\{R_D D - (1 - \delta + R)C - K_B, 0\}$. Hence, the net value of a loan to the lender if a tank is repossessed is $\delta C - K - R_D(C - D) - \max\{R_D D - (1 - \delta + R)C - K_B, 0\}$. Comparing the profits with and without repossession, we obtain the lender's loss per repossession:

$$L_{default}(D) = K - R_D D + \max\{R_D D - K_B, (1 - \delta + R)C\} \tag{3}$$

Let $E(D)$ denote net profits, which the lender maximizes over D. On the intensive margin, an increase in D will reduce tank repossession risk for existing borrowers since borrowers will be less willing to allow tanks to be repossessed if they lose a larger deposit. This is the treatment effect of D. On the extensive margin, an increase in the deposit will reduce the total number of loans and thus both the total profit from loans with no repossession and the expected loss from repossessions. This is the selection effect.

A greater deposit also directly reduces the lender's losses if borrowers fail to repay and proceeds from the tank sale are inadequate to cover the borrower's principal, interest, and tank repossession fee obligations. As noted before, this never occurs in our data.

The lender's problem is given by

$$\max_D E(D) = \max_D \left\{ \int_{\theta^*}^{\bar{\theta}} \left[P_{loan} - F(Y^R(s, D)) L_{default}(D) \right] dF_\theta(s) \right\} \tag{4}$$

where $P_{loan}(D)$ is the lender's profit per repaid loan and $\int_{\theta^*}^{\bar{\theta}} \left[F(Y^R(s, D)) \right] dF_\theta(s)$ is the number of tank repossessions for a given level of D.

The lender's first order condition for D^* will require equalizing the marginal cost and benefits of raising the required deposit:

$$-\frac{\partial\theta^*}{\partial D}f_\theta(\theta^*)P_{loan} = \int_{\theta^*}^{\bar{\theta}} F(Y^R(s,D^*))dF_\theta(s)L'_{default}(D^*) + \left[\int_{\theta^*}^{\bar{\theta}} \frac{\partial F(Y^R(s,D^*))}{\partial D}dF_\theta(s) - \frac{\partial\theta^*}{\partial D}F(Y^R(\theta^*,D^*))f_\theta(\theta^*)\right]L_{default}(D^*) \quad (5)$$

In the empirically relevant case, the deposit plus the resale value of the tank is great enough that the borrower has positive equity. Hence, in this case $L_{default}$ is not a function of D, thus $L'_{default} = 0$ and the FOC simplifies and can be written as:

$$\frac{\frac{\partial\theta^*}{\partial D}f_\theta(\theta^*)}{\frac{\partial\theta^*}{\partial D}F(Y^R(\theta^*,D^*))f_\theta(\theta^*) - \int_{\theta^*}^{\bar{\theta}}\frac{\partial F(Y^R(s,D^*))}{\partial D}dF_\theta(s)} = \frac{L_{default}(D^*)}{P_{loan}} = \frac{K-K_B}{(R-R_D)C} \quad (6)$$

Here, the left hand side is the ratio of marginal borrowers to marginal tank repossessions. In the empirical section we will measure this ratio. At the optimal deposit set by the lender, this ratio equals the ratio of the costs of a tank repossession to the profits from a successful loan.

In equating the marginal probability of a tank repossession times the cost of a tank repossession and the marginal probability of a successful loan times the profit from a successful loan, the lender will not consider the welfare effects of raising the required deposit on inframarginal customers who would have borrowed in any case. These customers will incur costs from an increase in the required deposit. This creates a wedge between the private and social benefits from raising the deposit requirement that will tend to make lenders choose deposit requirements that are too high from a social point of view. As long as the lender's profits are continuously differentiable in the deposit requirement, reducing the deposit rate slightly from the lender's profit maximizing level will generate a second-order reduction in profits, but a first order increase in welfare for infra-marginal borrowers.

Below we show that under our assumptions, a profit-maximizing lender will choose a deposit rate so high that there is a positive probability of tank repossession. If there were zero repossessions, the lender could lower the deposit, increasing the number of borrowers with a negligible increase in the repossession rate.

Lemma 1. *The profit-maximizing deposit rate will be such that there is some non-zero probability of repossession.*

Proof: see appendix.

This implies that profits will be continuously differentiable in the deposit, except for a kink at the point at which the deposit plus the resale value of the tank just covers the debt on the tank plus interest and the late fee, K_B. Denote this deposit level as D_F. Increases in D will increase loan recovery in the event of repossession only for D less than D_F. Above D_F, increases in D will affect profits only by charging the probability of tank repossession.

Unless the profit-maximizing deposit is at this kink point, a small change in the deposit will create a second-order change in profits for the lender, but a first-order loss in welfare for inframarginal borrowers. This generates our main result that in the presence of adverse selection generated by heterogeneous tank valuation, the lender chooses deposit requirements that are too stringent from a social point of view.[13]

Proposition 4. *If the profit-maximizing D^* is not D_F, i.e. that $R_D D^* + K_B - (1 - \delta + R)C \neq 0$ at the profit maximizing D^*, then the lender chooses deposit requirements that are too stringent from a social point of view, i.e., $D^* > D^{FB}$ where D^{FB} is the socially optimal deposit requirement.*

Proof. Social welfare is the sum of borrowers' utilities and lender's profit:

$$E(D) + \mathbb{U}_{total}(D),$$

where $\mathbb{U}_{total}(D)$ is the total utility of all the borrowers, given deposit requirement D.

If $R_D D - (1 - \delta)CQ - K_B \neq 0$, then D^* is characterized by the lender's FOC, which implies $\frac{\partial E(D)}{\partial D} = 0$. As we showed before, inframarginal borrowers prefer as low level of deposit as possible: $\frac{\partial \mathbb{U}_{total}(D;\lambda)}{\partial D} < 0$. Given the assumptions on the support of F, there will be inframarginal borrowers. Farmers who do not borrow will be indifferent to changes in D. Hence the derivative of the social welfare with respect to D is negative:

$$\frac{\partial E(D)}{\partial D} + \frac{\partial \mathbb{U}_{total}(D)}{\partial D} = \frac{\partial \mathbb{U}_{total}(D)}{\partial D} < 0.$$

[13] From the standpoint of an unconstrained social planner who seeks to maximize the sum of farmer utility and cooperative profits, the first best would be to allocate tanks to every farmer who has a valuation greater than RC. Repossessions consume resources, so would never take place. Farmers should always invest fully in their alternative investment opportunity. This could be implemented by setting deposits to zero, only allowing high valuation farmer borrow, and fully insuring farmers against shocks. The model does not incorporate risk aversion, but if there were even ϵ risk aversion, it would be optimal for farmers to be fully insured against income shocks.

One could also consider a mechanism design problem for a planner constrained by lack of information on individual specific tank valuations and income realizations. Such a constrained planner would face the problem of designing a mechanism in which farmers would reveal their tank valuations and income shocks. We will not attempt to solve this mechanism design problem, but the result that a small reduction in the deposit from the profit maximizing level will improve social welfare demonstrates that even a constrained social planner could generate higher welfare than a monopolist.

Thus, a social planner that takes farmer welfare into account will set a strictly lower D than would a profit-maximizing lender. $\square$

It is straightforward to extend the argument to show that distortions will persist even if the monopolist can offer a set of contracts, each consisting of an interest (R) and deposit (D) pair, and different farmers choose different pairs of R and D. Borrowers with low tank valuation will default with higher probability and hence will value a reduction in deposits more than borrowers who expect to default with low probability. A separating equilibrium, if one exists, will therefore involve at least two equilibrium contract offers, one selected by high valuation customers, with a high deposit and low interest rate and one for lower valuation customers with a lower deposit and a higher interest rate. The high deposit charged to high valuation customers will need to be high enough to deter low valuation farmers from choosing this contract and thus will be inefficiently high for the high valuation farmers.

Fundamentally, the distortion in the deposit requirement arises due to adverse selection, and thus is not limited to the case of a monopolist with an institutionally determined interest rate. To see this, suppose that there is free entry of lenders, and that lenders offer potential borrowers contracts consisting of an interest (R) and deposit (D) pair. Define a competitive equilibrium as a set of contract offers and acceptances such that all lenders make zero profits and all farmers maximize expected utility over the set of contracts and the option of not borrowing.

Proposition 5. *The competitive equilibrium will not be socially optimal.*

Proof: See appendix.

3.4 Discussion

We have treated the distribution of income as independent across farmers, but it is also worth considering the case in which $y_i = y_c + y_{ii}$ where y_c is a common shock, for example, due to weather or milk prices, and y_{ii} is an idiosyncratic farmer-specific shock and the common shock is observable, but idiosyncratic shocks are private information for farmers. In this case, requiring all borrowers to be insured against aggregate risk would reduce repossessions by addressing the moral hazard that arises if farmers allow tank repossession during periods of negative shocks, even when this is socially inefficient, because they do not face the full costs of repossession. Borrowing decisions will also be improved because farmers will face more of the full costs of borrowing, including the cost of the risk of default. Hence this will be part of optimal contract design. The optimal response to a common shock is thus insurance, rather than a greater deposit requirement.

The model could be extended in various ways. For simplicity and convenience, we wrote the model in terms of deposit requirements, but it could be extended to include guarantor requirements as well. If all farmers have access to the same outside investment opportunities, there is no gain from one farmer acting as a guarantor for another, but if some farmers do not have access to better investment opportunities than holding funds with the SACCO, then there would be potential gains if they could use their wealth to guarantee others'loans. Similarly, although the model considers the case in which the only negative credit outcome is tank repossession, we expect the model could be extended to include a vector of negative outcomes, including late payment. In such an extension, the decision maker's FOC for relaxing borrowing requirements would balance the gains from making additional profitable loans against the sum of the expected cost of each negative outcome times the change in the probability of that outcome.

This model abstracts from several features of the actual environment, for example, from the twenty-four month repayment schedule and the possibility of late payments. However, from the perspective of the lender, the key determinant of optimal borrowing requirements is how changing the borrowing requirement changes loan repayment outcomes at the margin. We observe these sufficient statistics for calculating the lender's profit-maximizing deposit rate empirically, so the details of exactly what generates the observed farmer behavior are not critical for determining the profit maximizing interest rate. The welfare conclusions will hold as long as tighter borrowing requirements select more profitable borrowers (as seems to hold empirically) and impose costs on inframarginal borrowers.

4 Project Design and Implementation

This section first discusses features of the loan contracts that were common across treatment arms and then discusses differences across treatment arms. (We focus on the main sample and describe some slight differences in the out-of-sample group at the end of the section.)

4.1 Common Loan Features Across Treatment Arms

All farmers in the project were offered a loan to purchase a 5,000-liter water tank. As a bulk purchaser of the tank, the SACCO was able to purchase tanks at the wholesale price and get free delivery to the borrowers' farm. In the main sample the wholesale price was KSh 4,000 (about $53) below the retail price and the SACCO passed these savings on to borrowers.[14] The price

[14] In this paper we use the dollar to Kenyan Shilling exchange rate at the time of the study which was approximately $1:KSh 75.

of the tank to the farmers, denoted C in the model, was KSh 24,000 (about $320), or roughly 20 percent of annual household consumption. Borrowers also incurred installation costs for guttering systems and base construction that averaged about KSh 3,400, or 14% of the cost of the tank. All farmers received a hand-delivered letter with the loan offer, and were given 45 days to decide whether to take up the loan. All loans were for KSh 24,000 and required an up-front deposit of at least KSh 1,000. The interest rate was 1% per month, charged on a declining balance.[15] Since the inflation rate is about 10% per annum, the real interest rate was very low. The 1% monthly interest rate is standard for SACCOs but is below the commercial rate. All treatment arms were charged a 1% late fee per month. The interest rate on a late balance was in the ballpark of the market range, but since processing late payments was labor intensive and costly for the lender, the lender was better off when borrowers paid on time. The amount due each month was automatically deducted from the payment owed to the farmer for milk sales. If milk payments fell short of the scheduled loan payment, the farmer was required to pay the balance in cash. Debt service represented 8.4% of average household expenditures and 11.4% of median expenditures at the beginning of the loan term. Collection procedures for late loans were as follows. When a farmer fell two full months of principal (i.e. KSh 2,000) behind, the SACCO sent a letter warning of pending default and providing two months to pay off the late amount and fees. The letter was hand-delivered to the farmer and followed up with monthly phone reminders. If the late payment was still outstanding after a further 60 days, the SACCO applied any deposits by the borrower or guarantors to the balance.

In arms other than the 100% cash collateralized arm (described below), it is possible that a balance would remain due after this. If a balance still remained, the SACCO gave the farmer an additional 15 days to clear it and waited to see if the next month's milk deliveries would be enough to cover the balance. If not, the SACCO would repossess the tank, charging a KSh 4,000 fee for administrative costs to the borrower from the proceeds of any tank sale. K_B was thus KSh 4,000. The full administrative costs associated with repossessing the tank, including the cost of hiring a truck, staff time, and security, was approximately KSh 8,500, so K should be considered to be at least KSh 8,500 and likely larger, since the lender also risked negative publicity or vandalism from repossession. The SACCO was the residual claimant on all loan repayments and was responsible for administering the loan. To finance the loans to farmers, Innovations for Poverty Action (IPA) purchased tanks from the tank manufacturer, which then delivered tanks to farmers. The SACCO arm of the cooperative then deducted loan repayments

[15]Charging interest on a declining balance is common in Kenya. Borrowers repaid a fixed proportion of the principal each month plus interest on the remaining principal. Borrowers were scheduled to repay KSh 1,000 of their principal back each month for 24 months. In the first month, when farmers had not repaid any of the KSh 24,000 principal, borrowers were scheduled to repay KSh 1240. In the second month, farmers were scheduled to repay KSh 1230; in the third month they were scheduled to repay KSh 1220; and in the final month farmers were scheduled to repay the final KSh 1,000 of their principal and KSh 10 in interest.

from farmer's savings accounts and remitted these payments to IPA, holding back an agreed administrative fee, structured so as to ensure the SACCO was the residual claimant on loan repayments. IPA financed the loan with a grant from the Bill and Melinda Gates Foundation. To ensure that the cooperative repaid IPA, the cooperative and IPA signed an agreement with the milk processing plant Brookside Dairy Ltd., which was the dairy's customer, itself one of the largest private milk producers and processors in the country, authorizing it to make loan repayments directly to IPA out of the milk payments to the cooperative.

4.2 Treatment Arms

As shown in Table 1, farmers were randomly assigned to one of four experimental loan groups, two of which were randomly divided into subgroups after uptake of the loans. One group was offered loans with the standard 100% cash collateral eligibility conditions typically offered by the cooperative (and by most other formal lenders in Kenya, including SACCOs and banks). Specifically, the borrower was required to make a deposit equal to one-third of the loan amount (KSh 8,000) and to have up to three guarantors deposit the other two-thirds of the loan (KSh 16,000) with the SACCO as financial collateral. Guarantors could either be those who already had savings or shares in the cooperative or those willing to make deposits. This group will be denoted Group C (for Cash collateralization).

A second group was offered the opportunity to put down a 25% (KSh 6,000) deposit, and to collateralize the remaining 75% of the loan with the tank itself. This group is denoted Group D (for deposit). In a third group, the borrower only had to put down 4% of the loan value (KSh 1,000) in a deposit and could find a guarantor to pledge the remaining 21% (5,000 KSh), bringing the total cash pledged against default to 25% of the loan amount. Like the deposit group, 75% of the loan could be collateralized with the tank itself. This group is denoted Group G (for guarantor). Comparing this guarantor group with the 25% deposit group isolates the impact of replacing individual with joint liability. In a final group, denoted Group A (for Asset collateralization), 96% of the value of the loan was collateralized with the tank itself and only a 4% deposit was required. In order to distinguish treatment and selection effects of deposit requirements, the set of farmers who took up the 25% deposit loans was randomly divided into two sub-groups. In one, all loan terms were maintained, while in the other, KSh 5,000 of deposits were waived one month after the deposit was made, leaving borrowers with a deposit of KSh 1,000, the same as borrowers in the 4% deposit group, A. The deposit (maintained) and deposit (waived) subgroups are denoted (D^M) and (D^W) respectively. Similarly, within the guarantor group, in one subgroup loan terms were maintained and in another subgroup the guarantors had their pledged cash returned and were released from liability in the case of default, and borrowers were informed of this. These guarantor-maintained and guarantor-waived subgroups are denoted (G^M) and (group G^W), respectively.[16] The selection effect of the deposit requirement on an outcome variable is the difference in the variable between all borrowers in the 4% deposit group and the 25% deposit group (waived) subgroup. The deposit treatment effect is the difference in a variable between the deposit (maintained) and deposit (waived) subgroups. Selection and treatment effects of the guarantor requirement are defined analogously.

5 Data and empirical specifications

In this section we discuss the sampling frame, randomization, data collection, and the empirical approach.

5.1 Sampling, Surveys, and Randomization

A baseline survey was administered to 1,968 households chosen randomly from a sampling frame of 2,793 households regularly selling milk to the dairy. 1,804 farmers were offered loans in accordance with the treatment assignment shown in Table 1. 419 farmers were offered 100% cash collateralized loans and 510 were offered 4% deposit loans.[17] 460 farmers took out loans..[18] Midline surveys were administered to all households in the sample, in part to check that tanks had been installed and were in use, but also to collect data on real impacts, including school participation and indicators of time use, based on asking what every household member did in the 24 hours prior to the survey. Subsequently a number of shorter phone surveys were administered, each of which focused on the three months prior to the survey. Time use information was collected from households in all groups,[19] while detailed production data was elicited from households in the 4% deposit group and the 100% cash collateralized group.[20] Finally, administrative data from the dairy cooperative was used to construct indicators of loan recovery,

[16]To avoid deception, at the time the loans were first offered, potential borrowers were told that they would face a 50% chance of having KSh 5,000 of the deposit requirement waived or of having the guarantor requirement waived, respectively.

[17]The groups with the least and most restrictive loan forms were the largest because this maximized power in picking up real effects of the loans. Loans were offered in three waves, since it was unknown *ex ante* how many farmers would borrow and the total capital available for purchasing tanks was limited.

[18]Loans were given in three phases, with contractual repayment periods running from March 2010 - February 2012; May 2010 - April 2012; and September 2010 - September 2012. (As discussed below, another set of loans in an out-of-sample group began in February 2012. The total number of loan offers that were prepared was 2616, but 19 of these offers could not be delivered, so the total number of loan offers that were delivered to farmers was 2597. When a household entered into a loan agreement, a water tank was delivered within a period of three months.

[19]Specifically, 1,699 households were interviewed in September 2011: 1,710 in February 2012; and 1,660 in May 2012.

[20]Data was collected from 901 respondents in 2011, and from 863 respondents in February 2012.

repossession, late payment collection actions[21], and early repayment. Table 2 reports F-tests for baseline balance checks across all treatment groups. Of the 26 indicators presented, one exhibits significant differences across groups at the 5-percent level, and two do so at the 10-percent level. This is in line with what would be expected when the assignment is indeed random. In part using the proceeds from the first set of loans, approximately 2600 additional farmers were offered loans between February and April 2012 (following a baseline survey in December 2011), providing an out-of-sample test. These loan offers were for KSh 26,000, due to an increase in the wholesale price of tanks. The monthly interest rate on these loans was 1.2% rather than one percent. We report data from this “out of sample" group on take up rates, loan recovery, and tank repossession outcomes. These farmers were randomly assigned to receive loan offers requiring only a KSh 1,000 deposit; a KSh 6,000 deposit; or KSh 5,000 from a guarantor plus a KSh 1,000 deposit. These deposits were the same value required in the first set of loan offers but, because the loan offer was for KSh 26,000 rather than KSh 24,000, they were slightly lower as a percentage of the loan amount: i.e. 4% deposit loans; 23% deposit loans; or 19% guarantor, 4% deposit loans. No farmers received the standard Nyala 100% cash collateralized loan offer in this out-of-sample group.

5.2 Empirical Approach

Empirical specifications typically take the form:

$$y_i = \alpha + \beta_A A_i + \beta_D^M D_i + \beta_D^W D_i^W + \beta_G^M G_i + \beta_G^W G_i^W + \varepsilon_i \quad (7)$$

where y_i is the outcome of interest, A_i, D_i^M and G_i^M are dummy variables equal to one if farmer i was randomized to Group A, D, or G, respectively, and D_i^W and G_i^W are equal to one for those members of the deposit and guarantor groups who had their obligations waived *ex post*. The base group in this specification is therefore Group C, the 100% deposit group. For some specifications, we add a vector of individual covariates, X_i. The overall average impact of moving from a 4% deposit requirement to a 25% deposit or guarantor requirement on take up or tank repossession or any other dependent variable is that given by the differences $\beta_D^M - \beta_A$ and $\beta_G^M - \beta_A$, respectively. The *ex post* randomized removal of deposit and guarantor requirements in groups D^W and G^W allows estimation of the selection and treatment effects of deposits and guarantors. In particular, the selection effects of being assigned to either the deposit or guarantor group are identified by $\beta_D^W - \beta_A$ and $\beta_G^W - \beta_A$, and reflect the extent to which greater deposit requirements or guarantor requirements select borrowers who behave differently than those who take up loans in the 4% deposit group due to differential selection. Under the model,

[21] E.g. receipt of a letter warning of pending default or reclamation of security deposit

this corresponds to selection of farmers with different tank valuations. Note that in the notation of the model, the loan take up rate corresponds to $1 - F(\theta^*(D))$ and the repossession rate corresponds to $\frac{F(\theta^R(D)) - F(\theta^*(D))}{1 - F(\theta^*(D))}$. Effects of changing the required deposit D, which we empirically estimate, correspond to changes in the relevant cutoff values. The selection effect corresponds to changes in $\theta^*(D)$ while the treatment effect corresponds to changes in $\theta^R(D)$. The repayment propensity of marginal farmers who are induced to borrow by being offered a 4% deposit requirement rather than a 25% deposit requirement is equal to the difference in repayment between the 4% and 25% deposit (waived) group, divided by the fraction of borrowers in the 4% group who would only borrow if in that group, e.g., the difference in loan take up rates between the 4% and 25% groups, divided by the take up rate in the 4% group. This corresponds to $\frac{F(\theta^R(6{,}000)) - F(\theta^R(1{,}000))}{[F(\theta^*(6{,}000)) - F(\theta^*(1{,}000))]/[1 - F(\theta^*(1{,}000))]}$ in the model. The treatment effects of borrowing requirements are identified by comparing loan repayment outcomes for borrowers who have the borrowing requirements maintained with loan repayments for borrowers who have borrowing requirements waived *ex post*. That is, any treatment effect of the deposit requirement would show up in a difference between β_D^M and β_D^W, while a treatment effect of the guarantors would be observed if β_G^M and β_G^W differed. The treatment effects of the deposit requirement would encompass the incentive effects of borrowing requirements in the model. Specifically, as the required deposit D decreases the cutoff value $\theta^R(D)$ falls. The effect of moving from $D = KSh\,6{,}000$ to $D = KSh\,1{,}000$ corresponds to $F(\theta^R(6{,}000)) - F(\theta^R(1{,}000))$ in the model.

6 Loan Take up Rates

Subsection 6.1 discusses the impact of borrowing requirements on loan take up and subsection 6.2 discusses the impact of borrowing requirements on observable borrower characteristics.

6.1 Impact of Borrowing Requirements on Loan Take Up

Allowing farmers to collateralize loans with the assets purchased with the loan greatly expands access to credit. In the original sample, 2.4% of farmers borrow under the standard SACCO contract with 100% cash collateralization (Group C); 27.6% - more than ten times as many - borrow when the deposit is 25% and the rest of the loan can be collateralized with the tank (Group D); and 44.3% borrow when 96% of the loan can be collateralized and only a 4% deposit is required (Group A) (See table 4). This implies that more than 40% of all targeted farmers would like to borrow at the prevailing interest rate and use this technology, but are not doing it because of borrowing requirements. To put this slightly differently, at least $(44.3 - 2.4)/44.3 = 95\%$ of potential tank purchasers would have been prevented from purchasing by credit constraints under the standard SACCO contract. Take up rates in the out-of-sample group are broadly comparable to those in the original experiment (Table 4), so in the combined sample, we estimate that 94% of those willing to borrow with a low deposit would be willing to borrow under the SACCO's original loan terms. This not only serves as a useful confirmation of the broad patterns in the data, but since farmers in the out-of-sample group had had a chance to see the original lending program in operation, it also provides some reassurance that the original results were not due to misconceptions regarding the water tanks or the loans, or to some unusual period-specific circumstances.[22] Our second finding is that joint liability does not increase credit access relative to the deposit requirement with individual liability. In the original sample, 27.6% of farmers borrow when they have to put up a 25% deposit themselves (Group D), but only 23.5% borrow when they can ask a friend or relative to put up all but 4% of the value of the loan (Group G) (Table 4). In the out-of-sample group, the point estimates of take up rates is higher in the 21% guarantor, 4% deposit group than in the 25% deposit group, but the difference is still not significant, and in the combined sample, there is almost no difference in take up (as seen in Table 4, columns 2 and 3). When we asked respondents why they did not seek guarantors, they said that they felt comfortable asking others to cosign loans needed to address emergencies, but not for a loan to improve their house. Anecdotal evidence suggests people care deeply about their reputations among friends and potential future guarantors, and they may not have wanted to risk these reputations. (Note that the evidence is also consistent with a model in which informal markets are so good that everyone is credit constrained to the same extent.)

The high elasticity of loan take up with respect to asset collateralization and the lack of response to joint liability points to a potential limitation of traditional joint-liability based microfinance and suggests that addressing barriers to asset collateralization, such as weak contract enforcement, may play an important role in addressing credit constraints.

6.2 Impact of Borrowing Requirements on Observable Borrower Characteristics

Do observable background characteristics differ between actual borrowers in the different loan groups? As shown in Table 3, we find some evidence that borrowers in the 4% arm are not as well off, but overall we find remarkably small differences in observable borrower characteristics among borrowers across arms. Columns (2)-(5) report borrower characteristics by arm. In column (1) these characteristics are reported for the whole sample, including borrowers and

[22]Point estimates suggest that, averaging across treatment arms, approximately 2.7% fewer members of "out-of-sample "group purchased tanks through the program. The difference is not statistically significant at the 5% level, but it is at the 10% level. One might expect some decline in tank purchases due to the increase in the price of the tank and the increased interest rate.

non-borrowers in all experimental arms. Of the 84 possible pair-wise comparisons,[23] we observe statistically significant differences at the 5% level in just four, almost exactly what would be expected under the null hypothesis of no differential selection on observables across treatment arms. Under the model, this suggests that the farmers with tank valuations intermediate between various levels of θ^* associated with different borrowing requirements are not that different on observables, suggesting that it would not be easy to screen borrowers on observables. That said, the variables in which there were significant differences mostly make sense in terms of the model. Borrowers in the 4% deposit group had lower log household assets than those in the 25% collateralized group and had lower log expenditures than those in both the deposit and guarantor groups. It is reasonable to think that poorer households might place less monetary value on a water tank than richer households, and thus might be disproportionately represented among those willing to borrow with a 4% deposit, but not under stricter borrowing requirements. Borrowers in the 4% group were also less likely to own a water tank than those in the 100% cash collateralized group. There is little evidence that strict borrowing requirements select borrowers who are substantially richer. Borrowers in the 100% cash collateralization arm do not have particularly high assets or expenditures (although standard errors are large).

The starkest difference between the (few) farmers in the 100% cash collateralized group who chose to borrow and farmers in other arms who chose to borrow is that the former typically chose to borrow only if they already owned a tank. 80% of borrowers already owned a tank, whereas only 43% of borrowers in the full sample owned tanks at baseline. Under the model, this could be interpreted as indicating that those who already owned tanks placed the highest value on them. Relaxing borrowing requirements induced non-tank owners to buy tanks. Relative to those who did not accept loan offers, borrowers tended to have more assets, higher per capita expenditure, more milk-producing cows, and more years of education, all of which might plausibly be associated with greater tank valuations under the model.[24] Under the model, differences between borrowers and non-borrowers would be starker than differences among borrowers across arms, if those with very low tank valuations, who would not buy even with a low deposit, differ on observables from those with high valuations, but those in an intermediate range of valuation are more similar on observables.

[23] $3! = 6$ pairs for each of 14 variables.

[24] There were few statistically significant differences between borrowers and non-borrowers in the 100% collateralized group, but there is little power to detect such differences in this group due to the small number of borrowers (see column [2]).

7 Impact of Borrowing Requirements on Loan Repayment

Subsection 7.1 discusses loan recovery and tank repossession, assessing evidence for selection and treatment effects of borrowing requirements. Subsection 7.2 provides a rough calibration of the model, and subsection 7.3 discusses late payment.

7.1 Loan Recovery and Tank Repossession

No tanks were repossessed with 75% asset collateralization under either the 25% deposit (Group D) or the 21% guarantor, 4% deposit condition (Group G) (Table 5). We also observe no tank repossessions when a 25% borrowing requirement was initially imposed and all but 4% of the deposit was later waived. Rates of tank repossession were 0.7% in the 4% deposit, 96% asset collateralized group (Group A). In particular, one tank was repossessed in the original sample and two more were repossessed in the out-of-sample group. In one out of those three cases the borrower paid off arrears and reclaimed the tank after the tank had been repossessed but before it had been resold.[25] Note that in all cases, proceeds from the tank sale were sufficient to fully pay off the principal and interest on the loan. The two tanks that were repossessed and then sold were purchased at KSh 29,000 and KSh 22,000).[26] There were thus no cases of loan non-recovery, defined as a failure to collect principal, interest, and late fee. Aside from the small 100% cash collateralized group (Group C), confidence intervals on loan non-recovery rates and on tank repossession rates are fairly tight, so we can reject even very low underlying probabilities of tank repossession. It is clearly impossible to use asymptotics based on the normal distribution when we observe zero or close to zero tank repossessions, but we can create exact confidence intervals based on the underlying binomial distribution. For example, in the combined 4% deposit group, all 431 loans were fully recovered (Table 5). We can therefore reject the hypothesis that the underlying loan non-recovery rate during the period of the loans was more than 0.69 percent. To see this, note that if the true rate was 0.69 percent, then the probability of observing at least one case of loan non-recovery in 431 loans would be $(1-0.0069)^{431}=0.05$. Using a similar approach with three tank repossessions, we can reject the hypothesis that the underlying tank repossession rate during the period was more than 2.02 percent or less than 0.14 percent. Table 5 displays Clopper-Pearson exact confidence intervals for the rate of tank repossessions and loan non-recovery under the point estimates for each loan type, calculated based on the combined sample, including loans from both the original sample and out-of-sample groups. (Clopper and

[25] We classify this case as a repossession since the costs of repossession were incurred.

[26] The high price relative to the loan value likely reflects the low depreciation rate on tanks as well as the fact that loans were based on the wholesale value of the tank.

Pearson, 1934).[27] While 25% borrowing requirements do not seem to select borrowers prone to tank repossession, borrowers selected by 4% requirements are more likely to have tanks repossessed. In particular, we can reject the hypothesis that the repossession rate is the same in the 4% deposit group as among a group combining both forms of 25% cash collateralization (e.g., combining the 25% deposit group and the 21% guarantor, 4% deposit group) at the 5.25% level. (Since the normal approximation is not a good approximation when the probability of an event is close to zero, we used Fisher's exact test to test for a difference between the repossession probabilities.) (As discussed below, after the end of the program, the SACCO began offering 75% asset-collateralized loans on its own, and there have been no tank repossessions. If one treated these observations as part of the sample, the p-value would be below 5%, but since these observations were not randomized and took place in a different time period, it is hard to quantify how much this should increase confidence that underlying tank repossession rates differ between samples with 75% and 96% asset-collateralized loans.) The sample size is inadequate to have this level of confidence for differences between the 96% asset-collateralized group and either the 25% deposit or guarantor group on its own. There is no evidence of treatment effects of stricter borrowing requirements on tank repossession, since tank repossession rates did not budge off zero when deposit or guarantor requirements were waived *ex post*. We also do not find differences in repossession between individual and joint liability.[28]

7.2 Calibration and Change in SACCO Policy Following the Program

While the model is stylized, and not meant to capture all features of the setting we examine, a rough calibration based on the results above and the first order condition for profit maximization suggests that moving to 96% asset collateralization would not have been profitable for the SACCO. We estimate that gains to farmers would exceed losses to the SACCO as long as farmers could have earned at least a 13% nominal rate of return on deposits required for

[27] A two-sided confidence interval can be calculated for cases with a nonzero number of events. Letting p denote the underlying true probability of an event (tank repossession or loan non-recovery), n the number of loans, and E the number of events, the probability of observing E or fewer events is given by $\sum_{i=0}^{E} \binom{n}{i}(1-p)^{n-i}(p)^i$. The upper limit of the confidence interval is calculated by solving for p in $\sum_{i=0}^{E} \binom{n}{i}(1-p)^{n-i}(p)^i = \frac{\alpha}{2}$, where α is the significance level.

Likewise, the probability of observing E or more events is given by $\sum_{i=E}^{N} \binom{n}{i}(1-p)^{n-i}(p)^i$. The lower limit of the confidence interval is calculated by solving for p in $\sum_{i=E}^{N} \binom{n}{i}(1-p)^{n-i}(p)^i = \frac{\alpha}{2}$. If there are zero events, the lower limit of the confidence interval is zero. In this case, we use a one-sided confidence interval with $\alpha = 0.05$ for the upper bound. In this event, the upper bound can be calculated by solving for p in $(1-p)^n = \alpha$

[28] See Carpena et al. (2013), Karlan and Giné (2014), and Giné et al. (2011) for other work on this issue.

tank loans. Changes in the SACCO policy following the program are consistent with the hypothesis that the SACCO did not see 96% asset-collateralization as profit-maximizing. As the model's FOC for lenders makes clear, the profit-maximizing deposit level depends not on the average rate of loan recovery and tank repossession, but on the ratio of the marginal additional tank repossessions associated with a change in D to the marginal increase in total loans. To calculate the marginal repossession rate in the combined sample from moving from 25% loans to 4% loans, i.e., D decreasing from KSh$6,000$ to KSh$1,000$, note that the average repossession rate is 0.7% for 4% deposit loans, so $F(\theta^R(1,000)) - F(\theta^*(1,000)) = 0.007\%$, and zero for 25% loans (Table 5, column 2), so $F(\theta^R(6,000)) - F(\theta^*(6,000)) = 0\%$. The take up rate for 4% deposit loans is 41.89%. For 25% deposit loans, the combined sample take up is 23.93%. Thus $\frac{F(\theta^*(6{,}000))-F(\theta^*(1{,}000))}{F(\theta^*(6{,}000))} = (41.89 - 23.93)/41.89 = 42.9\%$. In other words, 42.9% of those who borrow with a 4% deposit are marginal in the sense that they would not borrow with a 25% deposit. Thus our point estimate of the marginal repossession rate is $0.007/.429 = 0.0163$, implying that 1.63% or 1 in 62 of the marginal loans made under a 4% borrowing requirement would lead to a repossession.[29] Whether a lender would prefer the low deposit depends on whether the marginal profit for an extra loan is more than 1/62nd as much as the repossession costs that the lender bears, $K - K_B$, which we estimate to be at least KSh 4,500. In our context, the additional profits to the lender from a successful loan are likely extremely small. In particular, the difference between the interest rate of 3% per quarter that the SACCO pays on deposits and the interest rate of 1% per month that it charges borrowers amounts to only KSh 53 over two years on KSh 18,000 (the amount of the loan, less the 25% deposit, since the borrower earns interest on the deposit). Since interest is paid only on the declining balance, the SACCO makes even less than this on each successful loan. This is less than the expected loss from additional unreimbursed tank repossession costs, which are KSh 4,500/62 = KSh 73. Taking into account the costs to the SACCO of processing loans would further reinforce the conclusion that moving to a 4% deposit would not have been profitable.

The model suggests that the social welfare maximizing deposit rate will be lower than the profit-maximizing borrowing requirement. It seems highly likely that a 25% borrowing requirement is socially preferable to the SACCO's original borrowing requirements. [30] For plausible assumptions on borrowers'rate of return on alternative investments, 96% asset collateralization would be socially preferable to 75% asset collateralization. Unlike a profit-maximizing lender, a social planner will also take into account the benefits to the inframarginal borrowers of a lower

[29]The marginal repossession rates for the original sample group are quite similar. For the original sample group, a similar calculation implies that one out of 55 marginal loans leads to a repossession.

[30]Note that the SACCO's original 100% cash collateralization requirement is far above the level that would ensure full recovery of the principal and interest, plus a tank repossession fee in the case of repossession, so the conditions of the proposition that $D^* \neq D^{FB}$ is satisfied, and hence we can conclude that under the model the socially optimal deposit would be less than the 100% cash collateralization originally chosen by the SACCO.

deposit requirement. For every marginal borrower, there are $(100 - 42.9)/42.9 = 1.33$ inframarginal borrowers. Since R_D is 3% per quarter or 26.7% over the two-year life of the loan, inframarginal borrowers would give up (R_B^2 - 1.267) * KSh 5,000 on the alternative investment over the interest rate they earn on their SACCO deposits if they face a KSh 6,000 rather than KSh 1,000 deposit. Since there are 1.33 inframarginal borrowers for every marginal borrower, the social planner will prefer 96% asset collateralization to 75% asset collateralization, as long as $1.33 \times KSh5,000 * (R_B^2 - 1.267) > 0.0163 \times KSh4,500$, where the right hand side of this inequality represents the cost of additional tank repossessions that would not be internalized by borrowers. Solving for the level of R_B that makes the social planner indifferent implies that as long as inframarginal farmers have alternative investments yielding more than a 13 percent nominal return, the surplus created for inframarginal borrowers by reducing the deposit to 4% will exceed the extra net cost created for the lender. [31] The literature on rates of return to small enterprises in developing countries in general, and in Kenya in particular (e.g. Banerjee and Duflo, 2005; Duflo, Kremer and Robinson, 2008; Kremer, Lee Robinson, Rostapshova, 2011) suggests that the rate of return available to borrowers on other projects is far in excess of this cutoff value of nominal returns. Consistent with the calibration, after the end of the program, once the SACCO had learned about demand for loans and repayment rates under various conditions, it began using its own funds to offer 75% asset-collateralized loans to farmers, but not 96% asset-collateralized loans. The SACCO also introduced an appraisal fee on all its loans. For the tank loan, this is equal to KSh 700.

It seems reasonable to conjecture that the SACCO felt that with the addition of the KSh 700 fee, it was either profitable in expectation to lower the deposit requirement to 25% but not to 4%, or that the costs were low enough that the SACCO could afford to take this step as a way of improving members'welfare. It is not clear that it would have been profitable to lower the borrowing requirement to 25% without the KSh 700 fee, since the SACCO's margins on lending are so small, and the SACCO likely incurred additional administrative costs, including costs associated with late payments, by reducing borrowing requirements.

Based on knowledge of salaries in the SACCO and rough estimates of staff time allocation, we estimate that the cost of administering the additional loans would be at least roughly covered by the KSh 700 fee plus the margin the SACCO earns on the difference between the interest rate it pays its depositors and what it charges to borrowers. Our point estimates suggest that since allowing 75% asset collateralization did not lead to any additional tank repossessions, moving from requiring 100% cash collateralization to 75% asset collateralization would have been profitable during the period we examined. Of course while we observe no extra risk of tank

[31] In our sample, the lender always recovered K_B from sales of repossessed tanks, but the cutoff level of R_B increases only slightly, to less than a 14 percent nominal return, under the very conservative assumption that the lender would not be able to recover the repossession fee from the proceeds of the sale of repossessed tanks.

repossession, we cannot reject the hypothesis of an underlying increase in tank repossession of up to 0.32 percent with 75% asset collateralization. While it is not clear how one should model the objective function of the SACCO, since it is a cooperative, the fact that the cooperative did not lower the borrowing requirement to 4% after learning the results of the experiment suggests that reducing the borrowing requirement was not seen as profit maximizing. If it were profit maximizing, it would have been in the interest of all cooperative members, both borrowers and non-borrowers, to lower the deposit to 4%. While our calculations suggest that reducing the borrowing requirement to 4% might well have benefited borrowers, it would have reduced overall profits and thus harmed non-borrowers, which would include the median voter in the SACCO.

7.3 Late Payment

Table 6 presents late payment results for the 456 borrowers in the original sample for whom we have complete repayment data[32] Columns (1) to (3) report late payment outcomes during the loan cycle and columns (4) to (6) show payments that were late at the end of the two-year loan cycle. The notes below the table show the p-values on the existence of the selection effect that will drive wedges between private and social optima, as well as on the treatment effects. We first discuss overall effects and then selection and treatment effects. There is evidence of 'overall 'effects of different treatments. Those offered 100% cash collateralized loans are much less likely to be ever late than those in any other group, with point estimates of the difference ranging from 43 to 59 percentage points. Moving from a 100% cash collateralized loan to a 96% asset-collateralized, 4% deposit loan also increases issuance of pending default letters, and it increases late balances at the end of the loan cycle by KSh 222, or about $3. None of the ten 100% collateralized loans were late at the end of loan. This is a significantly smaller proportion than in the 4% deposit arm, but not than in the 25% deposit or guarantor arms. The extent to which loans were late, however, is tiny, as shown in Column (5) of Table 6, which reports the outstanding late balance at the end of the contractual loan period. Point estimates of the average late balance varied from 46 to 297 KSh, or less than one percent of the loan value. Mean months late in the other groups varied from 0.08 to 0.22 months, or 2-7 days. There is some suggestive evidence, significant at the 10% level, that stricter deposit and guarantor requirements select borrowers who are less likely to be ever late (Table 6, column 1). The 25% deposit requirements selects borrowers who are 11 $(57 - 46)$ percentage points less likely to be late at least once than the 4% deposit loan. Similarly, imposing a guarantor requirement leads to borrowers who are 14 $(57 - 43)$ percentage points less likely to be late ever. We find no significant treatment effect of either the deposit or guarantor requirements on being ever late. For other repayment outcomes,

[32] Data on the time of repayment are missing for four borrowers.

shown in other columns, there is little evidence of a selection effect. Column (2) reports whether a lender received a pending default letter at some point in the loan cycle (which was typically sent when a farmer was at least two months in arrears). There is no evidence of treatment and selection effects for the deposit group. There is only a borderline significant negative treatment effect of requiring a guarantor ($p = 0.10$). According to column (3), 11 percent of borrowers had security deposits reclaimed, with no significant differences between the treatment arms and the 4% deposit groups. We cannot reject the hypotheses of no treatment effect and of no selection effect. The model has only three periods, whereas the actual program took place over 24 months. In the last four months of the program, many farmers paid off their loans using their deposits, potentially creating a 'mechanical'effect through which larger deposits reduce late repayment that is not present the model.[33] For outcomes at the end of the cycle, which may be influenced by the mechanical effect, we see evidence of treatment effects in columns (4)-(6), but not much evidence of selection effects. Repaid late is a dummy variable equal to 1 if at the contractual maturity date the borrower has an outstanding balance left to pay. Column (6) in Table 6 shows the number of months by which full repayment of the loan was late (any farmers who paid early are counted as being zero months late.). There are significant treatment effects from the 25% deposit on “repaid late''and “months late.''Waiving the deposit increases the chance that borrowers are late at the end of the loan cycle by about 10 percentage points and increases the time by which loans miss the two-year end of the loan cycle by 11% of a month, or just over 3 days. This seems likely to be a mechanical effect. However, since the magnitudes are small, with the difference in the late balance less than 2 USD, these late balances themselves are unlikely to have a major impact on the profitability of lending. There is no evidence for treatment effects of guarantors on late payment outcomes.

Overall, our data does not indicate a consistent pattern in late repayment differences between the 4% and 25% groups. In three of the six measures of lateness, the point estimates indicate that there was greater late repayment in the 25% deposit group and in the other three cases the point estimates indicate there was greater lateness in the 4% loan group. It is difficult to quantify the extra administrative costs for the SACCO caused by higher rates of late payment due to reducing borrowing requirements. The SACCO made very few loans initially and handled much of the bookkeeping manually, in a way that avoided high fixed costs for software and for training staff, but that involved fairly high marginal costs for processing late payments. When payments were late, the SACCO had to manually calculate how late the payments were and send out letters. In principle it would be fairly easy to build a software system that would automate this process

[33] Although the existence of such a 'mechanical 'effect would make it difficult to decompose the treatment effect into incentive and mechanical effects, it would not interfere with distinguishing these treatment effects from the selection effects which generate a wedge between profit-maximizing and social welfare maximizing borrowing requirements.

and send out notices by text message. If a paper copy was needed this could be sent with milk transporters who visit farmers every day to collect milk which is delivered to the dairy daily.

One way to get a sense of the cost of late payment is to examine the extent to which the SACCO increased fees when it began making tank loans with a 25% down payment. As noted, the SACCO now applies a KSh 700 initial fee, just under three percent of the value of the loan. This suggests that KSh 700 was enough to cover both any perceived extra expected costs of tank repossession and any extra administrative cost of more frequent late payments caused by moving from the original SACCO contract to a 25% deposit contract.

One other striking feature of the data is that early repayment was common, as indicated in Table 7. It is surprising that so many farmers would forego a close to zero interest loan, since 95 percent of those who bought a tank under the 4% arm were sufficiently credit constrained that they would not purchase a tank under strict borrowing requirements. Column (2) in table 7 reports an indicator of "months early ", where any farmer who paid late is counted as having paid zero months early. Column (4) reports months of low-interest loan foregone by repaying early. This is equivalent to column (4) minus the non-waived deposit. Under the standard savings and credit cooperative contract, 90% of people in the 100% cash collateralized group repaid their loan early. On average, they were 15 months early on a 24 month contract. Even setting aside the eight months of principal in their deposit, they forewent seven months of low interest loan. Of course it is possible that some of these early payers took out new loans through the SACCO's ordinary lending program once their existing loans were paid off. However, since ordinary loans must be fully collateralized through own and guarantors'shares and deposits, paying off a loan early is still giving up access to capital. When 21% of the 25% deposit loan is waived (KSh 5,000 of a KSh 6,000 deposit), many households apply the waived funds almost fully to pay down the principal. They effectively stuck with the status quo of the contract that they signed, thus giving up KSh 5,000 of low-interest loan for more than one year.

8 Real Impact of Changing Borrowing Requirements

While micro-finance organizations often portray their loans as being for investment, there has been debate about the extent to which they actually are used for investment as opposed for financing consumption (Banerjee et al, 2015). Asset-collateralized loans might potentially be more likely to flow towards investment, since lenders making collateralized loans presumably have stronger incentives to ensure that borrowers actually obtain the assets than lenders making un-collateralized loans. In this section we show that loosening borrowing requirements for loans to purchase 5,000 liter rainwater harvesting tanks indeed led to increased investment in large tanks, although approximately one-third of the additional loans taken under the looser borrowing requirements may have been used to finance investments which would have taken place in any case. Since the rainwater harvesting tanks represent a new technology, our findings also provide evidence idea that access to credit may facilitate technology adoption.

Within the water literature, our findings are consistent with Devoto et al. (2011) in suggesting that expanding access to credit had real effects on access to water, and time use. Difference-in-difference estimates suggest that access to credit to purchase tanks also increased girls ' schooling. Table 8 presents ITT estimates of the impact of assignment to the 4% deposit group, as opposed to the 100% cash collateralized group, on tank ownership, water storage capacity, cow health, and milk production. These data were collected in a series of survey rounds for farmers in the two groups. We present our results in terms of a simple difference-in-differences framework, comparing these groups before and after loan offers were made. All specifications include survey round fixed effects. Assignment to the 4% deposit group (Group A) rather than the 100% cash collateralized group (Group C) increased the likelihood of owning any kind of tank by 17.5 percentage points, an increase of about 35% compared with the counterfactual (note that about 45% of all households had a tank at baseline) and led to an approximately 60 percent increase in household water storage capacity. Both increases are significant at the 1 percent level (as shown in columns 1 and 2). There is a 27% increase in ownership of a tank with 2,500 liter capacity or more. Since the difference in loan take up between Group C and Group A is approximately 40%, we estimate that approximately two-thirds of the additional loans generated new tank investments, while one-third financed purchases that would have taken place in any case. Standard errors on milk production are large, so while we find no significant effects on milk production, we also cannot rule out substantial effects,(Table 8). The point estimate is that log production increases by 0.047 points, but this is insignificant, with a t-statistic just under one (column 6). [34] There is evidence that farmers offered favorable credit terms were more likely to sell milk to the dairy to pay off their loans. Table 9 is based on monthly administrative data from the dairy on milk sales for farmers in all arms of the study. It compares the 4% deposit group (Group A) to all other groups using an ITT approach. Column 4 suggests more Group A farmers sold milk to the dairy. While assignment to the 4% deposit group does not significantly affect the quantity of sales (column 2 and 5), there is some evidence of an effect outside the top five percentiles during the period before loan maturation (although again this effect shows up only in differences, not in levels). Devoto et al (2011) find that household water connections generated time savings. Table 10 reports estimates of the impact of treatment assignment on time use and schooling for

[34] Table 8, column 4, suggests provision of water tanks reduced sickness among cows. Biologically, it is quite plausible that rainwater harvesting could improve cow health, because it reduced the need for cattle to travel to ponds or streams to drink and thus reduces their exposure to other cattle. However, since there were baseline differences in cow health (as reflected in the coefficient on treatment in this column), it is also possible that this simply reflects mean reversion.

children between the ages of 5 and 16. We present time-use results for the full sample (columns (1) and (2)), and separately for households with (columns (3) and (4)) and without (columns (5) and (6)) piped water. Odd-numbered columns measure time spent fetching water in minutes per day per household member, and even-numbered columns measure time spent tending livestock, again in minutes per day per household member. Treated girls spend 3.17 fewer minutes per day fetching water (significant at the 1% level). Boys spend 9.66 fewer minutes per day tending livestock, (significant at the 10% level) with smaller effects for girls that are not statistically significant (Columns 1 and 2, respectively). The greater access to credit for the purchase of tanks allows females in treatment households to make up nearly all of the gender differential (point estimate -2.22 minutes per day per female, column1, row 1) in time spent fetching water, significant at the 10 % level. Access to credit to purchase water tanks reduces girls' time tending livestock by 12 min/day in households with piped water. In households without piped water, it reduces boys' time tending livestock by 15 min/day. Difference-in-difference estimates suggest that greater access to credit also reduced school drop-out rates for girls (Table 11). Observations in each regression are at the individual child level, with standard errors clustered at the household level. Enrollment rates in general were very high at baseline, at about 98%for both boys and girls. Over time, some students dropped out, so these rates were 3-5 percentage points lower in the survey following the loan offers. While access to credit had no impact on boys' enrollment, girls in households assigned to the treatment group were less likely to drop out - the implied treatment effect on girls is 4 percentage points.

9 Conclusion

In high-income countries, households can often borrow to purchase assets with a relatively small down payment. In contrast, formal-sector lenders in low-income countries typically impose very stringent borrowing requirements. Among a population of Kenyan dairy farmers, we find credit access is greatly constrained by strict borrowing requirements. 42% of farmers borrowed to purchase a water tank when they could primarily collateralize the loan with the tank and only had to make a deposit of 4% of the loan value, but a small fraction (2.4%) borrowed under the lender's standard contract, which required that loans had to be 100% collateralized with pre-existing financial assets of the borrower and guarantors. Lower borrowing requirements are associated not only with increased borrowing, but with increased investment in the new technology. With regards to repayments, we find that when 75% of the loan could be collateralized with the tanks, all borrowers repaid in full. However, reducing required deposits to 4% of the loan value selected marginal borrowers with a 1.63% rate of failing to pay and having their tanks repossessed (although we see no moral hazard effect). Finally, we find no evidence that substituting guarantors for deposit requirements expands credit access, casting doubt on the extent to which joint liability can serve as a substitute for the type of asset-collateralization common in developed countries.

A simple adverse selection model suggests that since tight borrowing requirements select safer borrowers, profit-maximizing lenders will have socially excessive incentives to choose tight deposit requirements. A rough calibration of the model suggests that under the regulatory cap on interest rates, the profit-maximizing borrowing requirement likely exceeded the welfare-maximizing borrowing requirement. One policy implication is that legal and institutional barriers to using assets to collateralize debt could potentially have large effects on credit access, investment, and technology adoption. In general, weak property rights or contract enforcement could inhibit collateralization of loans with assets purchased with the loan. In our context, the lender experienced no problems repossessing collateral, and the key barrier to reducing borrowing requirements may have been financial repression in the form of regulatory limits on the interest rate SACCOs can charge customers. Adverse selection implies borrowing limits are too stringent, so regulatory limits on interest rates push in the wrong direction.[35]

A back of the envelope calculation suggests that only a small increase in the interest rate would be needed to offset the cost of the higher tank repossession rate among those who borrow with a 4% down payment.[36]

Financial repression can alternatively be relaxed through upfront fees. After seeing the results of the program, the SACCO introduced the financial innovation of imposing a KSh 700 initial fee and of reducing its deposit requirement to 25%. The fee provides an upper bound on the relaxation in financial repression needed to enable expanded credit access in our setting.

Note also that the SACCO could easily have covered the administrative costs of the program by retaining some portion of the approximately $50 gap between the wholesale price the SACCO paid for the tanks and the price at which tanks were sold to the farmer. In the program we examined, the tanks were sold to the farmer at the wholesale price, but if the SACCO charged farmers even 20% of the retail price markup, it could have raised this KSh 700 to cover administrative costs. [37]

[35] Note that this conclusion is robust to the possibility that shocks to income might be correlated across borrowers, and that repossession rates might have been higher in bad states of the world. Lenders will have private incentives to consider any such correlations in setting deposit requirements. Moreover, since aggregate shocks are observable, they are better addressed through insurance than through high deposit requirements.

[36] In particular, since one out of 62 marginal borrowers has a tank repossession, and since the extra cost incurred by the SACCO from a tank repossession is approximately KSh 4,500, an increase in profits per loan of KSh 4,500/62 = KSh 72.58 would have been enough to make this worthwhile for the lender in this particular season. This corresponds to an increase in the annual interest rate of approximately three tenths of one percent. In reality, a bigger increase might be needed, since lenders would also have to consider the cost of any additional late payments associated with moving to a 4% deposit rate.

[37] Indeed, we estimate that 30% of the wholesale-retail markup would be sufficient to cover not only the SACCO's

Increasing the fee for tank repossession could also increase the lender's incentives to reduce borrowing requirements. However, increasing the tank repossession fee would have undesirable risk-sharing properties since farmers will only experience tank repossession if hit by negative income shocks. Limited liability constraints might make it difficult to collect large repossession fees from defaulting borrowers.

The model does not, however, simply suggest removing barriers to asset collateralized loans. Insofar as we find that strict borrowing requirements select more profitable borrowers, the model suggests that profit-maximizing lenders will face (socially-excessive) incentives for tight borrowing requirements. The market failure identified in the paper creates a potential case for policymakers to encourage less restrictive borrowing requirements by subsidizing such loans - the opposite of existing regulatory policy. Of course, while we have argued that adverse selection will create market failures that lead to excessive borrowing requirements, there is also the danger of government failure, with large-scale government subsidies to allow lower borrowing requirements turning into favors for the politically connected and possibly triggering bailouts or costly SACCO failures if borrowing requirements dropped too low. Still, it may be possible to isolate particular types of subsidies that would be useful and that would limit the downside risk to the government.

First, most SACCOs are small and handle transactions manually, making administrative costs fairly high, and thus discouraging lending. Differences in productive efficiency and in administrative costs relative to loan value may partially account for differences in borrowing requirements between low and high-income countries. The development of better ICT technology for the sector could potentially radically lower the cost of handling late payments. Since it seems unlikely that the developer of better software for SACCOs could fully extract the social value of such software, subsidizing the creation of better software for managing SACCO accounts might be welfare improving. Second, studies that would shed light on the impact of relaxing borrowing requirements in contexts beyond the context of rainwater harvesting tanks and the dairy industry examined here would constitute public goods to the extent that their results might inform multiple lenders. Following the results of this study, not only did the Nyala SACCO relax its borrowing requirements, but a major commercial bank in Kenya (Equity Bank) has started a program with another tank manufacturer in which it is making loans to finance tank purchases.

More ambitiously, policymakers could offer to insure borrowers and/or lenders against observable negative shocks to the state of the world, such as droughts or price declines, potentially just offering bridging loans that would allow lenders to defer payment during such periods,

administrative costs of lending to farmers, but also the administrative costs of a larger entity lending to SACCOs. The fairly similar take up rates in the original sample and the out-of-sample group suggest that tank demand is not terribly price elastic, so it seems likely that there would be substantial tank demand even with somewhat higher prices.

with the loans still incurring interest.

One area we hope to explore in future work is whether prospect theoretic preferences could help explain why demand for loans is so responsive to the possibility of collateralizing loans using assets purchased with the loan and why repayment rates are so high. Under prospect theory (Kahneman and Tversky, 1979), people value gains relative to a reference point less than they disvalue losses relative to that reference point. Prospect theoretic agents may be averse to pledging an existing asset as collateral to obtain a new asset like a water tank, so they would have low take up rates when high deposits are required. However, prospect theoretic agents would be more likely to take up loans if they can use assets purchased with the loan as collateral, because this limits risk to existing assets. Once the tank is purchased, their reference point will shift, creating a strong incentive for prospect-theoretic farmers to retain possession. This could account for the very high repayment rates.

Prospect theory can also potentially explain the finding that the largest difference in observable characteristics between those borrowing in the 100% cash collateralized group and those borrowing in the other arms is that 80% of borrowers in the 100% cash collateralized loan arm already owned tanks. This is surprising from a diminishing returns perspective, but it is consistent with loss aversion, since most of the existing tanks are stone or metal and thus susceptible to loss from cracking or rust. Prospect theory might also help explain why farmers who made 25% deposits and later had them waived often simply applied the waived deposit toward paying down the loan early.

In future work, we hope to test whether people are more willing to collateralize loans using assets which they do not yet own, but would purchase under a loan, rather than assets which they already own. Such a test would involve randomly endowing people with one of two assets, and then comparing people's willingness to borrow to buy the other asset using either the endowed or non-endowed asset as collateral. It would also involve testing whether people are more likely to complete payments on an asset when it is already in their possession, through an asset-collateralized loan, than when it is not in their possession, as under a layaway plan.

Anderson, Michael (2008). "Multiple Inference and Gender Differences in the Effects of Early Intervention: A Reevaluation of the Abecedarian, Perry Presschool, and Early Training Projects," *Journal of the American Statistical Association*, 103(484), pp. 1481-1495.

Attanasio, Orazio, Britta Augsburg, Ralph De Haas, Emla Fitzsimons and Heike Harmgart (2015). "The Impacts of Microfinance: Evidence from Joint-Liability Lending in Mongolia," *American Economic Journal: Applied Economics*, 7(1), pp. 90-122.

Banerjee, Abhijit, Esther (2005)."Growth Theory through the Lens of Development Economics," *Handbook of Economic Growth*, pp. 473-552.

Banerjee, Abhijit, Esther Duflo, Rachel Glennerster and Cynthia Kinnan (2010)."The miracle of microfinance? Evidence from a randomized valuation," Working paper, MIT.

Banerjee, Abhijit, Dean Karlan, and Jonathan Zinman (2015). "Six Randomized Evaluations of Microcredit: Introduction and Further Steps," *American Economic Journal: Applied Economics*, 7(1), pp. 1-21.

Barrows, Richard, and Michael Roth. (1990). "Land tenure and investment in African agriculture: Theory and evidence, *The Journal of Modern African Studies*, 28(02), pp. 265-297.

Beck, Thorsten, and Asli Demirguc-Kunt (2006). "Small and medium-size enterprises: Access to finance as a growth constraint, " *Journal of Banking and Finance*, 30(11), pp. 2931-2943.

Besley, Timothy J. (1994). "How do market failures justify interventions in rural credit markets? , " *The World Bank Research Observer*, 9(1), pp. 27-47.

Besley, Timothy J. and Stephen Coate (1995). "Group Lending, Repayment Incentives and Social Collateral, " *Journal of Development Economics*, 46(1), pp. 1-18.

Carpena, Fenella, Shawn Cole, Jeremy Shapiro and Bilal Zia (2013). "Liability Structure in Small-scale Finance. Evidence from a Natural Experiment, " *World Bank Economic Review*, 27(3), pp. 437-69.

Casaburi, Lorenzo, and Rocco Macchiavello (2014). "Reputation, Saving Constraints, and Interlinked Transactions: Evidence from the Kenya Dairy Industry," Working paper, Warwick

Casey, Katherine, Rachel Glennerster, and Edward Miguel (2012). "Reshaping Institutions: Evidence on Aid Impacts Using a Pre-Analysis Plan," *Quarterly Journal of Economics*, forthcoming.

Clingingsmith, David, Asim Khwaja, and Michael Kremer (2009)."The Impact of the Hajj: Religion and Tolerance in Islam's Global Gathering," *Quarterly Journal of Economics*, 124(3), pp. 1133-1170.

Clopper, C.J and Egon S. Pearson (1934). "The use of confidence or fiducial limits illustrated in the case of the binomial," *Biometrika*, (26), pp. 404-413.

Crépon, Bruno, Florencia Devoto, Esther Duflo and William Parienté (2011). "Impact of microcredit in rural areas of Morocco: evidence from a randomized evaluation," Working paper, MIT.

de Mel, Suresh, David McKenzie and Christopher Woodruff (2008). "Returns to capital in microenterprises: evidence from a field experiment," *Quarterly Journal of Economics*, 123(4), pp. 1329-1372.

de Mel, Suresh, David McKenzie and Christopher Woodruff (2009). "Are women more credit constrained? Experimental evidence on gender and microenterprise returns," *American Economic Journal: Applied Economics*, 1(3), pp. 1-32.

Devoto, Florence, Esther Duflo, Pascaline Dupas, William Parienté and Vincent Pons (2011). "Happiness on tap: piped water adoption in urban Morocco," Working paper, MIT.

Djankov, Simeon, Caralee McLiesh and Andrei Shleifer (2007). "Private credit in 129 countries," *Journal of financial Economics*, 84(2), pp. 299-329.

Duflo, Esther, Michael Kremer, Jonathan Robinson (2008). "How High Are Rates of Return to Fertilizer? Evidence from Field Experiments in Kenya," *American Economic Journal*, 98(2), pp. 473-552.

Enterprise Survey Data (2015). "Finance," World Bank.

Esrey, Steven A. (1996). "Water, waste, and well-being: a multicountry study," *American Journal of Epidemiology*, 143(6), pp. 608-623.

Fafchamps, Marcel, David McKenzie, Simon Quinn and Christopher Woodruff (2011). "When is capital enough to get female microenterprises growing? Evidence from a randomized experiment in Ghana," NBER Working Paper Series, Working Paper 17207.

Feder, Gershon and David Feeny (1991). "Land tenure and property rights: theory and implications for development policy," *The World Bank Economic Review*, 5(1), pp. 135-153.

Feigenberg, Ben, Erica Field and Rohini Pande (2012). "The economic returns to social interaction: experimental evidence from microfinance," Working paper, Harvard.

Field, Erica, Rohini Pande, John Papp and Natalia Rigol (2010). "Term Structure of Debt and Entrepreneurial Behavior: Experimental Evidence from Microfinance", Working paper, Harvard.

Giné, Xavier and Dean Karlan (2011). "Group versus individual liability: short and long term evidence from Philippine microcredit lending groups," Working paper, Yale.

Giné, Xavier, Karuna Krishnaswamy and Alejandro Ponce (2011). "Strategic Default in Joint Liability Groups: Evidence from a Natural Experiment in India," mimeo, World Bank.

Giné, Xavier, Jessica Goldberg, and Dean Yang (2012)."Credit Market Consequences of Improved Personal Identification: Field Experimental Evidence from Malawi", *American Economic Review*, forthcoming.

Hermes, Niels, and Robert Lensink (2007). "The empirics of microfinance: what do we know?" *The Economic Journal*, 117(517), F1-F10.

Kahneman, Daniel and Amos Tversky (1979). "Prospect theory: An analysis of decision under risk, " *Econometrica: Journal of the Econometric Society*, 47(2), pp. 263-291.

Karlan, Dean and Jonathan Zinman (2009). "Observing unobservables: identifying information asymmetries with a consumer credit field experiment," *Econometrica*, 77(6), pp. 1993-2008.

Karlan, Dean and Xavier Giné (2014). "Group versus Individual Liability: Short and Long Term Evidence from Philippine Microcredit Lending Groups," *Journal of Development Economics*, 107, pp. 65-83.

Kling, Jeffrey, Jeffrey Liebman, and Lawrence Katz (2007). "Experimental Analysis of Neighborhood Effects," *Econometrica*, 75(1), pp. 83-119.

Kremer, Michael, Jean Lee, Jonathan Robinson and Olga Rostapshova (2011). "The return to capital for small retailers in Kenya: evidence from inventories," Working paper, World Bank.

Kristjanson, Patricia M., Brent Murray Swallow, Gareth Rowlands, R.L. Kruska and P.N. De Leeuw (1999). "Measuring the costs of African animal trypanosomosis, the potential benefits of control and returns to research," *Agricultural systems*, 59(1), pp. 79-98.

La Porta, Rafael, Florencio Lopez-De-Silanes, Andrei Shleifer and Robert W. Vishny (1997). "Legal Determinants of External Finance," /emphThe Journal of Finance, 52(3), pp. 1131-1150.

Luoto, Jill, Craig McIntosh, Bruce Wydick (2007). "Credit Information Systems in Less Developed Countries: A Test with Microfinance in Guatemala," *Economic Development and Cultural*

Change, 55(2), pp. 313-334.

McKenzie, David and Christopher Woodruff (2008)."Experimental evidence on returns to capital and access to finance in Mexico," *World Bank Economic Review*, 22(3), pp. 457-482.

Microcredit Summit Campaign (2014). Data reported to the campaign in 2013,

Morduch, Jonathan (1999). "The microfinance promise, " /emphJournal of Economic Literature, 37(4), pp. 1569-1614.

Nicholson, Mark (1987). "The effect of drinkingfrequency on some aspects of the productivity of Zebu cattle," *Journal of Agricultural Science*, 108(1), pp. 119-128.

Peden, Don, Faisal Ahmed, Abiye Astatke, Wagnew Ayalneh, Mario Herrero, Gabriel Kiwuwa, Tesfaye Kumsa, Bancy Mati, A. Misra, Denis Mpairwe, Girma Tadesse, Tom Wassenaar and Asfaw Yimegnuhal (2007). "Water and livestock for human development," in D. Molden (ed.), *Comprehensive assessment of water management in agriculture*, Oxford University Press, Oxford, pp. 485-514.

Place, Frank and Shem E. Migot-Adholla. (1998). "The economic effects of land registration on smallholder farms in Kenya: evidence from Nyeri and Kakamega districts, *Land Economics*, Vol. 73, No. 3., pp. 360-373.

Rajan and Zingales. (1998) "Financial Dependence and Growth," *The American Economic Review*, Vol. 88, No. 3. (Jun., 1998), pp. 559-586.

The SACCO Societies Regulatory Authority. (2013) "Sacco Supervision Annual Report 2013 (Deposit Taking Saccos), http://www.sasra.go.ke/index.php/resources/publications#.VqfjDvkrI1k.

Staal, S.J., I. Baltenweck, O. Bwana, G. Gichungu, M. Kenyanjui, B. Lukuyu, K. Muriuki, H. Muriuki, F. Musembi, L. Njoroge, D. Njubi, A. Omore, M. Owango and W. Thorpe (2001). "Dairy systems characterisation of the greater Nairobi milk shed," Smallholder Dairy Project Research Report.

Stiglitz, Joseph and Andrew Weiss (1981). "Credit rationing in markets with imperfect information," *American Economic Review*, 79(1), pp. 159-209.

Wang, Xia, and Paul Hunter (2010). "A systematic review and meta-analysis of the association between self-reported diarrheal disease and distance from home to water source," *The American Journal of Tropical Medicine and Hygeine*, 83(3), pp. 582-584.

Water for People (No date), About. http://www.waterforpeople.org/about/.

White, Gilbert F., David J. Bradley, and Anne U. White (1972). Drawers of water. Chicago: University of Chicago Press.

WHO and UNICEF (2010), Progress on Sanitation and Drinking Water: 2010 update. World Health Organization (WHO) and

UNICEF: Joint Monitoring Programme for Water Supply and Sanitation.

World Bank (2012), World development indicators onlinedatabase, http://data.worldbank.org/data-catalog/world-development-indicators.

World Bank (2014), Global financial inclusion database, http://datatopics.worldbank.org/financialinclusion/.

Zeller, Manfred, Aliou Diagne, and Charles Mataya (1998). "Market access by smallholder farmers in Malawi: Implications for technology adoption, agricultural productivity and crop income," *Agricultural Economics*, 19(1), pp. 219-229.

A Proofs for the Model Section

Proposition 1. *Conditional on having taken out a loan and an income realization y_i, a farmer will repay the loan if and only if the farmer's tank valuation, θ, is greater than a repayment threshold, $\theta^R(y_i, D)$, where θ^R is decreasing in D.*

Proof. If the borrower obtains too low a realization of income, and liquidates a portion of her non-tank investments in order to repay the lender, her utility is

$$U_{repay}(y_i, D; \theta_i) = \theta_i + R_B(w - RC + y_i) + (R_D - 1)D, \tag{8}$$

i.e., the benefit of the tank, θ_i, plus the gross return on non-liquidated non-tank investments. The borrower owes the principal and interest payments, RC, which she must pay off using her income, y_i, the deposit, D, and liquidating $RC - y_i - D$ of initial wealth, and thus will earn a return on the remaining non-liquidated assets of $R_B(w - RC + y_i))$. To derive the utility of a borrower who does not repay the loan and allows the tank to be repossessed, we first derive the payment the borrower receives from the sale of the tank. In the event of repossession, a borrower will receive their net equity in the tank if it is positive and get no money back if their net equity is negative. The net equity of the borrower is equal to the total value of the tank and the deposit, $R_D D + \delta C$, minus the total claims of the lender in the event of repossession, $RC + K_B$. Hence, the borrower will receive $\max\{R_D D - (1 - \delta + R)C - K_B, 0\}$ in the event of a repossession and the total borrower utility in the event of repossession is

$$U_{repossession}(y_i, D; \theta_i) = y_i + (w - D)R_B + \max\{R_D D - (1 - \delta + R)C - K_B, 0\}. \tag{9}$$

The terms represent the utility borrowers obtain from their period two endowment y_i, the gross return on non-tank investment $(w - D)R_B$, and any proceeds from the sale of the tank, $\max\{R_D D - (1 - \delta + R)C - K_B, 0\}$. Repossessions only occur when low income is realized, since high-income farmers will not need to liquidate investments to repay the tank loan and farmers will not borrow if they know that in all states of the world, they will allow the tank to be repossessed.[38] Comparing the utilities from liquidation and repossession yields the condition for repossession, conditional on borrowing at $t = 1$. A borrower will only fail to repay the loan and allow the tank to be repossessed if she earns low income and the utility from repossession exceeds the utility from liquidation of investments:

$$U_{repossession}(y_i, D; \theta_i) \geq U_{repay}(y_i, D; \theta_i), \tag{10}$$

Under the assumed conditions on the distribution of tank valuations, there is a marginal farmer with valuation $\theta^R(y_i, D)$, which given an income realization y_i, is indifferent between liquidating assets and allowing repossession.

[38] Recall that in the model, the benefits of the tank are not incurred until period 3, so if a tank is repossessed the farmer obtains no benefit, but still incurs the repossession fee.

$$\theta^R = (1 - R_B)y_i + (RC - D)R_B + (1 - R_D)D + \max\{R_D D - (1 - \delta + R)C - K_B,\ 0\} \quad (11)$$

The comparative statics is trivial.

Additionally, under the conditions on the distribution of tank valuation assumed earlier, a marginal level of income exists, denoted by $Y^R(\theta_i, D) \in (\underline{Y}, \bar{Y})$, at which a farmer with valuation θ_i is indifferent between liquidating other assets to repay the loan allowing the tank to be repossessed.

$$Y^R = \frac{1}{R_B - 1}\left[-\theta_i + R_B(RC - D) - (R_D - 1)D + max\{R_D D - (1 - \delta + R)C - K_B, 0\}\right] \quad (12)$$

Then,

$$\frac{\partial Y^R}{\partial D} \leq -\frac{R_B - 1}{R_B - 1} < 0 \quad (13)$$

and

$$\frac{\partial Y^R}{\partial \theta_i} = -\frac{1}{R_B - 1} < 0. \quad (14)$$

□

Proposition 2. *Farmers will borrow if $\theta_i > \theta^*(D)$, where θ^* is increasing in D. Hence, the repossession rate will be:*

$$\int_{\theta^*(D)}^{\bar{\theta}} F_Y(Y^R(\theta, D))dF_\theta(s), \quad (15)$$

and this repossession rate will be decreasing in the deposit rate D.

Proof. At period $t = 1$, farmer i will borrow if utility from not borrowing is lower than expected utility from borrowing. The utility farmers receive if they do not borrow, denoted as $\bar{U}$, is equal to their period two income y_i plus their gross return on investing all of their period one wealth in non-tank investments, $R_B w$. Borrowers will allow their tanks to be repossessed if they have a low income realization, $y_i \leq Y^R(\theta, D)$. Then, the borrower's expected utility from borrowing will be equal to the expectation over all possible income outcomes that include income realizations that lead to repossession, $U_{repossession}(y_i, D; \theta_i)$, and that lead to keeping the tank, $U_{repay}(y_i, D; \theta_i)$. A farmer will borrow if the expected utility from borrowing exceeds the expected utility from not borrowing, $\bar{U} = \mathbb{E}y_i + R_B w$. Hence, a farmer will borrow if

$$\int_{\underline{Y}}^{Y_i^R} U_{repossession}(y_i, D; \theta_i)dF_Y(y_i) + \int_{Y_i^R}^{\bar{Y}} U_{repay}(y_i, D; \theta_i)dF_Y(y_i) \geq \bar{U}. \quad (16)$$

Note that the value $U_{repay}(y_i, D; \theta_i)$ depends on whether $y_i > Y^H$ or not, where Y^H is the income level at which some of the alternative investment has to be liquidated: $Y^H = RC - D$.

As before, given the assumptions on the support of the cumulative distribution function $F(\theta_i)$, a marginal farmer exists, denoted by $\theta^*(D; \lambda) < \bar{\theta}$, who is indifferent whether to borrow. Higher valued farmers will borrow while lower valued farmers will not. Thus, the mass of farmers who borrow is given by $1 - F(\theta^*(D))$. Take the derivative of equation (16) at θ^* with respect to D (notice that the terms that correspond to the derivatives of Y_i^R and Y^H cancel out):

$$\int_{\underline{Y}}^{Y^R} \left[\frac{\partial U_{repossession}}{\partial D} + \frac{\partial U_{repossession}}{\partial \theta}\frac{\partial \theta^*}{\partial D}\right] dF_Y(y_i) + \int_{Y^R}^{\bar{Y}} \left[\frac{\partial U_{repay}}{\partial D} + \frac{\partial U_{repay}}{\partial \theta}\frac{\partial \theta^*}{\partial D}\right] dF_Y(y_i) = 0. \tag{17}$$

Then,

$$\begin{aligned}\frac{\partial \theta^*}{\partial D} = -\frac{\int_{\underline{Y}}^{Y^R} \frac{\partial U_{repossession}}{\partial D} dF_Y(y_i) + \int_{Y^R}^{\bar{Y}} \frac{\partial U_{repay}}{\partial D} dF_Y(y_i)}{\int_{\underline{Y}}^{Y^R} \frac{\partial U_{repossession}}{\partial \theta} dF_Y(y_i) + \int_{Y^R}^{\bar{Y}} \frac{\partial U_{repay}}{\partial \theta} dF_Y(y_i)} =\geq \\ \geq \frac{\left(1 - (F_Y(Y^H) - F_Y(Y^R))\right) R_B + (F_Y(Y^H) - F_Y(Y^R)) - R_D}{1 - F_Y(Y^R)} > 0\end{aligned} \tag{18}$$

Notice that $\left(1 - (F_Y(Y^H) - F_Y(Y^R))\right) R_B + (F_Y(Y^H) - F_Y(Y^R)) - R_D \geq (1 - F_Y(RC))R_B + F(RC) - R_D > 0$, since $F_Y(RC) \leq F_Y(Y^H) - F_Y(Y^R)$.

The repossession rate is decreasing in the deposit rate D, because θ^* is increasing in D (adverse selection) and Y^R is decreasing in D (moral hazard). □

Proposition 3. *If $(1 - F_Y(RC))R_B + F_Y(RC) > R_D$, farmers with $\theta_i > \theta^*(D)$ are strictly better off with a lower deposit, and those with $\theta_i < \theta^*(D)$ are indifferent to marginal changes in D. If farmers are not credit constrained - that is, $R_B \leq R_D$ - then the deposit requirement does not affect the decision of whether to borrow.*

Proof. To see that farmers with $\theta_i > \theta^*(D)$ are better off with a lower deposit, first note that saving through the SACCO, yielding R_D, is always possible for farmers, regardless of whether they take out a tank loan. Secondly, a lower required deposit allows farmers to make other investments that yield higher returns than deposits in the SACCO: in particular, inframarginal borrowers are negatively affected by high deposit requirements, because with higher deposit requirements, more funds that could potentially go to higher value uses are tied up in deposits. Farmers who are not borrowing are indifferent to small changes in D.

To see that the absence of credit constraints implies that D does not affect the decision to borrow, note that if $R_B \leq R_D$, farmers will want to invest all their initial wealth with the SACCO. Hence, farmers never have to liquidate alternative investments in order to repay the loan, implying that $U_{repay}(y_i, D, \theta_i) = \theta_i + y_i - (RC) + R_D w$, which does not depend on the deposit requirement, D. As a result, the repayment decision does not depend on the income realization and repayment is certain for every θ_i. Hence, $Y^R \in \{\underline{Y}, \bar{Y}\}$ - that is, every borrower either takes the loan and repays it with certainty, or does not take the loan in the first place.[39] This decision depends only on the valuation of the tank θ_i. That is, farmers would only borrow if their value

[39] As explained in the proof of proposition 1, farmers will not borrow if they know that in all states of the world, they will allow the tank to be repossessed.

of having a tank is higher than the cost of the tank, $\theta^* = RC$, and this condition does not depend on the size of deposit requirement.. $\square$

Lemma 1. *The profit-maximizing deposit rate will be such that there is some non-zero probability of repossession.*

Proof. Assume the contrary. Note that our assumptions on initial parameters allow for the case in which $Y_i^R = \underline{Y}$ for sufficiently large values of θ and D. Let $\theta^R(D)$ denote the lowest tank valuation at which the farmer never allows repossession. Then, the profit-maximizing deposit requirement, D^*, must be such that $\theta^*(D^*) \geq \theta^R(D^*)$. Then, note that $\int_{\underline{\theta}}^{\bar{\theta}} \frac{\partial F(Y^R(s,D^*))}{\partial D} dF_\theta(s) = 0$ and $F(Y^R(\theta, D^*)) = 0$ for any $\theta \geq \theta^R$. These facts imply $\frac{\partial E}{\partial D} < 0$ which produces a contradiction. $\square$

Proposition 5. *Under competition, the competitive equilibrium will not be socially optimal. Lenders will choose deposit requirements $D^* > D^{FB}$.*

Proof. Note that all borrowers would prefer lower interest rates and lower deposit levels, but borrowers with low valuations of the tank, who anticipate a greater probability that they might choose not to repay the tank loan, will put higher weight on reductions in deposits relative to reductions in interest rates than will borrowers with high tank valuations. Note also that in the social optimum, farmers with high tank valuation, such that $\theta_i > R_D C$, will obtain a tank, and, assuming $(1 - F_Y(RC))R_B + F_Y(RC) > R_D$, they will invest all of their wealth in the alternative asset rather than making a deposit on a tank loan. To see that this cannot be a competitive equilibrium, it is sufficient to show that a contract in which lenders offer a zero deposit contract cannot be a competitive equilibrium. Suppose that this were part of a competitive equilibrium. There will be some corresponding amount of interest, ($R(0)$) that implies that firms offering this contract will make zero profits. This candidate equilibrium will either need to be a separating equilibrium or a pooling equilibrium. If it is a pooling equilibrium, then a lender could profitably deviate by offering a slightly higher deposit and a slightly lower interest rate, such that the high valuation borrowers would accept the contract, but low valuation borrowers would not. It could not be a separating equilibrium, because in any separating equilibrium low valuation customers particularly value low deposits, and hence in any separating equilibrium, low valuation customers would choose a low deposit and a high interest rate, and high valuation customers would choose a high deposit and a low interest rate. $\square$

Table 1: Program design

Treatment (loan) description	Deposit amount (KSh)	Guarantor amount (KSh)	Collateralization with tank (KSh)	Offers
4% deposit (A)	1,000	0	23,000	510
100% cash collateralized loan (C)	8,000	16,000	0	419
25% deposit loan, maintained (D^M)	6,000	0	18,000	225
25% deposit loan, waived (D^W)	6,000 $\rightarrow$ 1,000	0	18,000	225
21% guarantor loan, 4% deposit, maintained (G^M)	1,000	5,000	18,000	225
21% guarantor loan, 4% deposit, waived (G^W)	1,000	5,000 $\rightarrow$ 0	18,000	200

Note: Loan amount is KSh 24,000 for all treatment groups.
All amounts in KSh (roughly KSh 75=$1)

Table 2: Baseline randomization checks

	Mean	F-test stat	P-value
Milk production (Aug 2009 - Jan 2010)			
(1) Average monthly milk production	207.4	1.229	0.297
(2) Monthly milk per cow	133.2	0.523	0.719
(3) Monthly cows calved down	0.103	2.691**	0.030
Milk sales (Aug 2009 - Jan 2010)			
(4) Monthly sales to dairy	69.01	1.175	0.320
(5) Sold milk to dairy dummy	0.480	2.129*	0.075
Livestock (Aug 2009 - Jan 2010)			
(6) At least one cow died	0.318	0.539	0.707
(7) At least one cow got sick	0.516	2.091*	0.080
(8) Zerograzing dummy	0.177	0.265	0.901
(9) Zero or semi-zerograzing dummy	0.749	1.899	0.108
Assets			
(10) Household assets (ln KSh)	12.27	0.976	0.420
(11) Value of livestock (ln Ksh)	11.29	1.038	0.386
(12) Monthly cows producing milk	1.660	1.858	0.115
(13) Baseline piped water	0.315	0.726	0.574
(14) Own water tank	0.428	0.256	0.906
(15) Own water tank > 2500 liters	0.241	0.444	0.777
Schooling			
(16) Kids (5-16) enrolled in school	0.975	0.302	0.877
(17) Girls (5-16) enrolled in school	0.980	0.554	0.696
(18) Boys (5-16) enrolled in school	0.970	0.261	0.903
Household characteristics			
(19) Household head education (years)	8.459	1.193	0.312
(20) Female household head	0.201	0.603	0.660
Time use (minutes per day)			
(21) Farming	87.0	1.298	0.269
(22) Livestock	77.2	0.665	0.616
(23) Fetching water	14.3	1.556	0.184
(24) Working	38.8	0.172	0.953
(25) School (Girls 5-16)	330.5	0.647	0.629
(26) School (Boys 5-16)	336.3	1.033	0.390

Note: Milk volumes in liters per month. Reported means are across all six loan groups. The F-stat tests for equality of means across all six loan groups. Certain time use variables are omitted due to space constraints. One excluded time use variable (socializing with neighbors) has a significant F-test statistic. Including the ten omitted time use variables, we conduct baseline checks on 39 variables. Standard errors are clustered at the household level when necessary.

* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

Table 3: Borrower characteristics across arms

	(1) Full sample incl. non-borrowers	(2) 100% collateralized borrowers	(3) 25% deposit borrowers	(4) 4% deposit 21% guarantor borrowers	(5) 4% deposit borrowers
(1) Log household assets	12.28	12.30	12.60	12.68	12.44
	[0.02]	[0.25]	[0.10]	[0.10]	[0.06]
(2) Log per capita expenditure	10.37	10.36	10.56	10.64	10.41
	[0.02]	[0.10]	[0.07]	[0.07]	[0.04]
(3) Avg cows producing milk	1.67	1.80	1.94	2.04	1.93
	[0.03]	[0.18]	[0.17]	[0.17]	[0.08]
(4) Milk per cow (liters)	142.7	142.7	163.9	143.6	148.4
	[2.27]	[23.57]	[10.34]	[10.34]	[5.91]
(5) Monthly sales to dairy (liters)	78.2	86.3	106.1	89.3	115.1
	[4.14]	[32.96]	[13.44]	[13.44]	[22.99]
(6) Education (years) of HH head	8.46	10.30	9.78	9.08	9.14
	[0.11]	[1.54]	[0.36]	[0.36]	[0.30]
(7) Female HH head	0.20	0.20	0.18	0.24	0.15
	[0.01]	[0.13]	[0.03]	[0.03]	[0.02]
(8) Girls as % of HH	0.13	0.05	0.13	0.11	0.10
	[0.00]	[0.04]	[0.01]	[0.01]	[0.01]
(9) Piped water access	0.32	0.40	0.27	0.30	0.34
	[0.01]	[0.16]	[0.04]	[0.04]	[0.03]
(10) Own tank	0.43	0.80	0.49	0.46	0.49
	[0.01]	[0.13]	[0.05]	[0.05]	[0.03]
(11) Own big tank (> 2500 L)	0.24	0.40	0.30	0.33	0.24
	[0.01]	[0.16]	[0.04]	[0.04]	[0.03]
(12) Number of big tanks	0.32	0.40	0.41	0.43	0.30
	[0.02]	[0.16]	[0.07]	[0.07]	[0.04]
(13) Practice zero grazing	0.18	0.20	0.18	0.19	0.23
	[0.01]	[0.13]	[0.03]	[0.03]	[0.03]
(14) Practice zero/semi zerograzing	0.75	1.00	0.81	0.77	0.80
	[0.01]	[0.00]	[0.04]	[0.04]	[0.03]

Note: Standard errors in brackets.
All data is pre-treatment. Log per capita expenditure is measured in log Kenya shillings per year.
There are significant differences between borrowers and non-borrowers at the 5% level in the first three rows, columns (3)-(5); row 5, columns (4) and (5); row 6, column (5); row 10, column (2); row 11, column (4); and row 14, column (3).

Table 4: Loan take-up rates and standard errors

	Original sample		Out of sample loans		Combined data		
	Loans taken up/offers	Rate (percent)	Loans taken up/offers	Rate (percent)	Total loans taken up/offers	Overall Rate (percent)	P-value of difference (percent)
100% cash collateralized loan (C)	10/419	2.39			10/419	2.39	
		[0.75]				[0.75]	
25% deposit loan (D)	124/450	27.55	233/1042	22.36	357/1492	23.93	0.031
		[2.11]		[1.29]		[1.10]	
21% guarantor, 4% deposit loan (G)	100/425	23.53	261/1036	25.19	361/1461	24.71	0.50
		[2.06]		[1.35]		[1.13]	
4% deposit (A)	226/510	44.31	205/519	39.50	431/1029	41.89	0.12
		[2.20]		[2.15]		[1.54]	

Note: The original sample loans were offered during March 2010, May 2010, and June 2010. The out of sample loans were offered Feb to April 2012. Standard errors shown in brackets. Standard errors calculated as $SE = \sqrt[2]{p(1-p)/n}$, where p is the percentage of loan take-up and n is the number of offers.

Table 5: Tank repossession and loan non-recovery rates: combined sample

Group	Tank repossession		Loan non-recovery	
	Count	Rate (percent)	Count	Rate (percent)
4% deposit (A)	3/431	0.7	0/431	0
		(0.14, 2.02)		(0, 0.85)
25% deposit (D)	0/357	0	0/357	0
		(0, 0.83)		(0, 0.83)
21% guarantor, 4% deposit (G)	0/361	0	0/361	0
		(0, 0.83)		(0, 0.83)
100% cash collateralized (C)	0/10	0	0/10	0
		(0, 25.89)		(0, 25.89)
Treatment effect on repossession p value	0.0525			

4% deposit = 25% deposit or guarantor

Note: Tank repossession and loan non-recovery data include loans from the original sample and out of sample groups. Of the three tank repossessions in the 4% group, one repossession was in the original sample while two were in the out-of-sample group. 25% deposit or guarantor refers to the aggregate of the 25% deposit and 21% guarantor, 4% deposit groups. 95% Clopper-Pearson exact confidence intervals are displayed in parentheses under the point estimates for each of the rates. One-sided tests were conducted for cases with zero repossessions. Treatment effect on repossession is obtained by conducting Fishers Exact Test for the difference between rates of 4% deposit and 25% deposit or guarantor groups. Note that including the additional 152 loans the Nyala cooperative has offered independently, the p-value is 0.0362.

Table 6: Late repayment

	During loan cycle			Late at end loan		
	(1)	(2)	(3)	(4)	(5)	(6)
	Late ever	Rec'd pending default letter	Security deposit reclaimed	Repaid late	Late balance (KSh)	Months late
4% deposit loan	0.57***	0.29***	0.09***	0.12***	221.79***	0.13***
	[0.11]	[0.03]	[0.02]	[0.02]	[50.02]	[0.03]
25% deposit loan, maintained	0.59***	0.33***	0.16***	0.02	45.67	0.02
	[0.12]	[0.06]	[0.05]	[0.02]	[33.04]	[0.02]
25% deposit loan, waived	0.46***	0.28***	0.08**	0.12***	161.90**	0.13***
	[0.12]	[0.06]	[0.04]	[0.04]	[66.76]	[0.05]
21% guarantor loan, 4% deposit, maintained	0.51***	0.18***	0.10**	0.06*	101.91	0.08*
	[0.13]	[0.05]	[0.04]	[0.03]	[63.43]	[0.05]
21% guarantor loan, 4% deposit, waived	0.43***	0.32***	0.14***	0.14***	297.52***	0.22**
	[0.13]	[0.07]	[0.05]	[0.05]	[111.67]	[0.09]
Constant(100% secured joint-liability loan)	0.11	0.00	0.00	0.00	0.00	0.00
	[0.11]	[0.00]	[.]	[.]	[0.00]	[.]
Deposit Selection Effect P-value	0.10	0.97	0.80	0.99	0.47	0.99
25% dep loan waived = 4% dep loan						
Guarantor Selection Effect P-value	0.07	0.64	0.38	0.66	0.54	0.34
25% guar loan waived = 4% dep loan						
Deposit Treatment Effect P-value	0.13	0.55	0.2	0.02	0.12	0.03
25% dep loan maintained = 25% dep loan waived						
Guarantor Treatment Effect P-value	0.42	0.10	0.54	0.18	0.13	0.16
25% guar loan maintained = 25% guar loan waived						
Mean of dependent variable	0.64	0.28	0.11	0.10	180.36	0.12
Observations	456	456	456	456	456	456

Note: * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$. Heteroskedasticity-robust standard errors in brackets.

Table 7: Early repayment

	(1) Repaid early	(2) Months early	(3) Months of principal in deposit	(4) Foregone months of low interest loan	(5) Months of repayment freed by waiver
100% cash collateralized loan (C)	0.900	15.000***	8	7.000***	–
	[0.100]	[2.431]		[2.431]	
25% deposit loan, maintained (D^M)	0.594	5.500***	6	−0.500	–
	[0.062]	[0.835]		[0.835]	
25% deposit loan, waived (D^W)	0.383	4.957***	1	3.957***	5
	[0.063]	[1.113]		[1.113]	
4% deposit, 21% guarantor loan, maintained (G^M)	0.560	3.804***	1	2.804***	–
	[0.071]	[0.810]		[0.810]	
4% deposit, 21% guarantor loan, waived (G^W)	0.320	5.214***	1	4.214***	–
	[0.067]	[1.281]		[1.281]	
4% deposit loan (A)	0.239	1.875***	1	0.875***	–
	[0.028]	[0.322]		[0.322]	

Note: * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

Table 8: Real impacts on water access, cow health, and milk production: 4% deposit arm versus 100% cash collateralized arm

	(1) Own tank	(2) Log total capacity	(3) Own large tank	(4) Any cow was sick	(5) Production	(6) Log production
Treat*Post	0.175^{***}	0.609^{***}	0.265^{***}	-0.133^{***}	0.831	0.047
	[0.023]	[0.083]	[0.030]	[0.036]	[12.979]	[0.048]
Treatment	-0.051	-0.174	-0.046^{*}	0.102^{***}	12.473	-0.033
	[0.033]	[0.109]	[0.028]	[0.033]	[12.566]	[0.052]
Constant	0.445^{***}	6.932^{***}	0.253^{***}	0.449^{***}	221.331^{***}	5.207^{***}
	[0.027]	[0.095]	[0.024]	[0.025]	[8.419]	[0.037]
Dep Var Mean	0.518	7.114	0.334	0.409	311.554	5.532
Round FE	Yes	Yes	Yes	Yes		
HH Clustering	Yes	Yes	Yes	Yes	Yes	Yes
Observations	2649	1830	1830	5099	5151	4960

Note: All household survey data is collapsed by survey round (Nov 2011, Feb 2012, May 2012, and Sept 2012). All endline household survey data was collected only in the 100% cash collateralized and the 4% deposit treatment groups.
In column (3), owning a large tank refers to owning a tank that can hold at least 2500 liters of water.
Milk production is reported in liters.
Standard errors clustered at the household level are reported in brackets.
* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

Table 9: Milk sales

	(1)	(2)	(3)	(4)	(5)	(6)
	Sold milk	Milk sales	Milk sales, 5% trim	Sold milk	Milk sales	Milk sales, 5% trim
Treat*Post	0.034*	1.851	8.942*	0.037**	7.379	10.246**
	[0.018]	[13.269]	[4.898]	[0.017]	[6.070]	[4.703]
Treat*Post loan maturation				−0.010	−0.330	−3.854
				[0.019]	[6.913]	[5.476]
Treatment	−0.021	−2.428	−6.623	−0.021	−4.216	−6.623
	[0.017]	[10.708]	[5.124]	[0.017]	[6.541]	[5.125]
Constant	0.484***	44.517***	45.222***	0.484***	45.893***	45.222***
	[0.018]	[8.310]	[4.299]	[0.018]	[5.259]	[4.299]
TreatPost + TreatPost Maturation				0.028	7.049	6.393
SE				0.025	8.675	6.893
Dep Var Mean	0.690	186.474	159.187	0.690	159.187	131.890
Month FE	Yes	Yes	Yes	Yes	Yes	Yes
HH Clustering	Yes	Yes	Yes	Yes	Yes	Yes
Observations	78476	78476	74556	78476	77693	74556

Note: All data is from administrative sources and covers all treatment groups.
Data is for each household for each month from July 2009 to May 2013.
Milk sales are reported in liters.
Treatment is defined as being offered a 4% deposit loan.
In column (3) and (6), sales are trimmed by excluding the top five percent of sales.
All specifications include month fixed effects.
Standard errors clustered at household level are reported in brackets.
* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

Table 10: Time use impacts on children 5-16 (minutes per day)

	Full sample		Piped water		No piped water	
	(1) Fetching water	(2) Tending livestock	(3) Fetching water	(4) Tending livestock	(5) Fetching water	(6) Tending livestock
Treatment*Female	−2.21*	5.57	−2.35	−16.56*	−1.98	13.61*
	[1.32]	[6.15]	[2.24]	[9.81]	[1.61]	[7.57]
Treatment	−0.96	−9.66*	0.45	5.01	−1.55	−14.84**
	[1.03]	[5.72]	[1.53]	[8.73]	[1.27]	[7.13]
Female	3.30***	−28.05***	2.94*	−18.47**	3.33**	−31.64***
	[1.09]	[5.27]	[1.74]	[7.31]	[1.34]	[6.67]
Constant	8.11***	30.59***	6.30**	25.11***	8.86***	32.81***
	[1.14]	[4.57]	[1.89]	[6.01]	[1.38]	[5.91]
Effect for Girls	−3.171***	−4.085	−1.902	−11.554**	−3.525**	−1.232
SE	[1.182]	[3.748]	[1.693]	[4.879]	[1.458]	[4.748]
Dep Var Mean	5.515	28.356	3.438	25.539	6.246	29.346
Observations	4109	4109	1069	1069	3040	3040

Note: All time use variables are in minutes per day per child. Analysis includes data from the early 2011 follow-up, Sept 2011, Feb 2012, May 2012, and Sept 2012 surveys. All specifications include time (survey round) fixed effects. Standard errors clustered at the household level are reported in brackets.

* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

Table 11: School enrollment impacts of tanks (children, 5-16)

	(1) Enrolled girl (5-16) dummy	(2) Enrolled boy (5-16) dummy
Treatment*Post	0.040**	−0.009
	[0.019]	[0.020]
Treatment	-0.012	0.001
	[0.012]	[0.011]
Post	−0.047***	−0.034**
	[0.016]	[0.016]
Constant	0.984***	0.983***
	[0.008]	[0.009]
Observations	1088	1080

Note: Enrollment variable equals one if the child is enrolled in school.

Panel observations only, so observations are excluded if the child was younger than five at baseline. Aging of the sample thus likely accounts for downward trend in enrollment captured by the coefficient on Post.

Standard errors clustered at the household level.

* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$