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

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Abstract

Do the stringent formal sector borrowing requirements common in many developing countries restrict credit access, technology adoption, and welfare? When a Kenyan dairy's savings and credit cooperative randomly offered some farmers the opportunity to replace loans with high down payments and stringent guarantor 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 did not affect loan take up.) There were no repossessions among farmers allowed to collateralize 75% of their loans, and only 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 lowered deposit requirements, but not of moral hazard. A simple model and rough calibration suggests that adverse selection may deter lenders from making welfare-improving loans with lower deposit requirements, even after introducing asset collateralization. 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-sector lenders in developing countries often impose very tight borrowing requirements, such as high deposit requirements or guarantor requirements. To the extent that these requirements restrict credit access, investment, technology adoption, and welfare, there may be a strong case for steps to encourage lenders to loosen these borrowing requirements, for example by loosening regulatory caps on interest rates, strengthening legal and contract enforcement insitutions to expand the scope for collateralization of debt, or even subsidizing lenders to loosen borrowing requirements. While the evidence summarized in Banerjee et al. (2015) suggests both limited take up and limited impact of standard microfinance contracts, it is possible that other contracts have more potential.

We examine the impact of replacing loans with high down payments and stringent guarantor requirements with asset- collateralized loans, similar to the mortgages and car loans that are common in developed countries. In particular, we studied a Kenyan dairy's saving and credit cooperative which randomly offered different borrowing conditions to different members. Its standard borrowing conditions required that one third of loans be secured with deposits by the borrower, and that the remaining two thirds be secured with cash or shares from guarantors. Allowing borrowers to collateralize loans for water tanks using assets purchased with the loans dramatically increased borrowing. Only 2.4% of farmers borrowed under the savings cooperative's standard borrowing conditions. The loan take up rate increased to 23.9% under 25% deposit or guarantor requirements and 75% tank-collateralization. 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. Results were similar in a separate out-of-sample test.

However, we 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.

Defaults did not increase with moderate deposit requirements and asset collateralization. In particular, there were no tank repossessions when 75% of the loan could be collateralized with the tank itself and 25% was collateralized with deposits from the borrower and/or guarantors. Reducing the deposit requirement 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 adverse selection, rather than the treatment effects associated with moral hazard.

A simple model suggests that under adverse selection, a lender with market power facing interest rate caps, such as the savings and credit cooperative we study, will set deposit requirements above the socially optimal level even with asset collateralization. To see this, 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 suggests that the cooperative could increase profits by moving to 75% but not 96% asset collateralization, but that for reasonable parameter values total welfare would be greater with 96% collateralization. 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.

With regards to investments, we find that those offered the opportunity to collateralize 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 primary contributions of this paper are twofold. First, we extend the literature on asset-collateralized loans in developing countries. Existing literature on transition and developed economies (Aretz, Campello, and Marchica 2016, Calomiris et al. 2016) provides evidence that when institutional reforms at the national level expand collateralization options, borrowing increases at both the extensive (higher loan takeup) and intensive (more leverage) margins. One such expansion of collateralization options is the enhancement of the ability to collateralize loans with the assets that they are used to purchase (Assuncao et al. 2014).[1] Our context allows identification from randomization at the level of individual loans. The result is a novel estimate of the direct impact on loan uptake of replacing a high-deposit loan with an asset-collateralized, low-deposit loan. Secondly, we measure how repossession rates vary under different loan contracts, and use a Karlan-Zinman test to decompose the effect of lower deposit requirements on repossession into moral hazard and adverse selection effects.[2] Our empirical model builds on the results of the Karlan-Zinman test to suggest that even after asset-collateralization is allowed, lenders will set deposit requirements which are too high from a social welfare standpoint. The calibration of the model supports this conclusion for our empirical context.

We also provide results that contribute to the literature on credit access in the developing world. 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). 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. Feder et al. (1988) explore the association of credit uptake with joint liability and asset collateralization, and find evidence that the association with collateralization is stronger.

[1]Skrastins (2016) also considers asset collateralization, examining how institutional design can facilitate easier collection of debt and collateral.

[2]For a similar decomposition of deposit requirement changes into moral hazard and adverse selection effects in the developed context, see Adams, Einav and Levin (2009).

The rest of the paper is organized as follows: Section two provides background on smallholder 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 and tank repossession, 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.

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).[3]

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 negative consequences for schooling.[4] Devoto (2013) finds that provision of household water

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

[4]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.

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).[5]

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 almost all farmers are familiar with the product, 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

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

or to another dairy, which would have involved higher transport costs.[6]

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.[7] SACCOs 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. Fi-

[6]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.

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

nally, 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.

3 Model[8]

In order to help motivate the empirical work in subsequent sections, we present a simple model following Stiglitz and Weiss (1981).

In Section 3.1 we lay out assumptions . Borrowers value tanks and have concave utility over other consumption. We allow potential borrowers to vary in their valuation of tanks (for example due to factors like distance from water supplies, labor availability in the household, and taste for clean water), and in initial wealth. Given their wealth and tank valuations as well as the deposit required by the lender, potential borrowers choose whether to borrow to buy a tank, in which case they must use some of their wealth for the deposit, constraining (and possibly binding) their first period consumption. Remaining wealth can be used for first-period consumption or additional savings for period 2. Borrowers then receive stochastic income and choose whether to repay the loan or allow the lender to repossess the tank.

In section 3.2, we first consider the problem of a borrower deciding whether to repay given the borrower's first period savings (which must be at least equal to the deposit selected by the lender), tank valuation, and income realization. We then solve backwards to the problem of

[8]We thank Egor Abramov, William Glennerster, Matthew Goodkin-Gold, Matthew Lilley, Itzchak Raz, and Kevin Xie, for their help on this section.

a potential borrower deciding whether to take out a loan given their initial wealth, their tank valuation, and the required deposit. We show that if potential borrowers are credit constrained, high deposit requirements will have a selection effect on repayment in which they screen out low-valuation or low-wealth borrowers who are relatively unlikely to repay. High deposit requirements will also have a treatment effect on repayment conditional on borrowing, lowering the threshold tank valuation above which borrowers choose to repay the loan for each possible period-two income realization.

In section 3.3, we work back further to the problem of the lender choosing the size of the required deposit. To reflect our institutional context, we consider a monopoly lender with exogenously fixed interest rates. We show that, because the lender fails to internalize the cost to credit-constrained inframarginal borrowers of a high deposit requirement, it will choose stricter deposit requirements than would be socially optimal.

3.1 Assumptions

Borrower 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 and risk-reduction benefits. There is a continuum of potential borrowers, with water tank valuation continuously distributed over the interval $[\underline{\theta}, \bar{\theta}]$ according to some cumulative distribution function $F(\theta)$. Potential borrowers value consumption of a composite good c as well as water tanks, with preferences for potential borrower i represented by a utility function $U(\theta_i, c) = u(c_1) + u(c_2) + \theta_i I_2(T)$, where $u' > 0, u'' < 0$ and $\lim_{c \to 0} u' = \infty$ and $I_2(T)$ is an indicator for owning a tank at period $t = 2$. c_1 and c_2 represent the composite good in each of the two periods. For simplicity, discounting and net present discounted value weightings are set aside, and we assume utility does not depend on tank ownership in period 1, $I_1(T)$.

Potential borrower i has an initial wealth w_i at period $t = 1$. w_i is drawn from the interval $\left[\underline{W}, \overline{W}\right]$ according to the distribution $F_w(\cdot)$. The realized value of w is private information, known only to the borrower. Income at period $t = 2$ is denoted y_i and drawn from the interval

$[\underline{Y}, \overline{Y}]$ according to distribution $F_y(\cdot)$. The realized value of y is also private information, known only to the borrower.

The distributions of initial wealth, water tank valuation and income are independent, have positive densities throughout their supports, and have no mass points

Potential borrowers can purchase tanks at price P in period $t = 1$ through a contract with the lender in which they must repay $R_T P$ at $t = 2$, where R_T is the gross interest rate. If they purchase a tank, then in period $t = 2$ they choose whether to repay the loan or allow the tank to be repossessed. We assume that the support of θ is wide enough that some potential borrowers are not willing to purchase tanks at full cost, but every potential borrower would purchase a tank if it were free. In particular, assume that $0 < \underline{\theta}$, and even under the best income draw $\overline{Y}$, the agent with lowest endowment $\underline{W}$ and valuation $\underline{\theta}$ prefers consumption to the tank, and thus when y_i is unknown will not purchase the tank.[9]

If farmers borrow to buy a tank, they must make a deposit of at least the lender's requirement D, which earns a gross interest rate R_D. (The lender chooses the required deposit, but borrowers take it as a parameter.) Potential borrowers may also allocate wealth to savings. They also earn gross interest R_D on any saving. Gross savings, including the value of the tank deposit, are denoted S, so for those who borrow to purchase a tank, overall savings $S \geq D$, while those who do not purchase a tank are not subject to this constraint. In order to ensure the model reflects a market with credit-constrained borrowers and adverse selection effects on equilibrium outcomes, we make two assumptions. The first is that, for any deposit requirement D, there exist marginal borrowers. Specifically, we assume that the support of W and θ are wide enough that a farmer with period-1 wealth $\underline{W}$ and tank valuation $\underline{\theta}$ will not borrow even when D=0, and a farmer with period-1 wealth $\overline{W}$ and tank valuation $\overline{\theta}$ will purchase a a tank even when D=P. The second assumption is that at least some borrowers are credit constrained for any deposit requirement D. Specifically, we assume the deposit requirement causes some potential borrowers to be credit constrained if they undertake the tank investment, in the

[9]This condition is assumed to hold for any reasonable deposit requirement, i.e. any D between 0 and P.

sense of constraining their first period consumption below the level that would be optimal were the deposit not mandated. Since marginal utility is decreasing in consumption and consumption is always higher under default than repayment, a sufficient assumption for there to exist agents who are credit constrained is $u'(\underline{W}) > R_D\mathbb{E}(u'(y_i - R_T P))$. We call borrowers who satisfy $u'(w) > R_D\mathbb{E}(u'(y_i - R_T P))$ "definitely credit-constrained." To ensure that a nonzero mass of credit-constrained farmers will choose to borrow, we assume that for any D, there is some w_i such that $u'(w_i - D) > R_D\mathbb{E}(u'(y_i + R_D D - R_T P))$, and an agent with initial wealth w_i and tank valuation $\overline{\theta} - \epsilon$ for some $\epsilon > 0$, will choose to borrow a tank. Liquidity constraints make holding wealth in the SACCO costly and are thus consistent with our empirical result that greater deposit requirements reduce loan take up dramatically.However, the model also admits individuals who are not credit constrained, and for sufficiently high w_i these individuals will optimally choose $S > D$ (such that higher c_1 could have been chosen). We make a final assumption that $\underline{W}$ and $\underline{Y}$ are large enough so that repayment of loan principal and interest is always feasible ex ante, $\underline{W}R_D + \underline{Y} > R_T P$.[10] This assumption is more accurately thought of as a simplification: in the case that wealth levels are such that some farmers may find themselves unable to pay off the tank, our assumptions on u are such that such farmers will never borrow, regardless of the level of D, and thus we can ignore them for the purpose of the model and restrict our attention to those farmers for whom repayment is always feasible ex ante.

There is a limited liability constraint so that if the borrower fails to repay, the only assets which the lender can seize are the pledged deposit D and the tank. If the tank is repossessed, it is sold for δP[11] and the lender is repaid the principal and interest, as well as a repossession fee, K_B. Leftover proceeds from the sale, if they exist, are returned to the borrower. We let D_F denote the deposit level at which the principal, interest, and repossession fees are exactly covered by the deposit and tank sale proceeds. We also allow for the possibility that default

[10]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).

[11]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 P in our context, and indeed one repossessed tank sold for more than the wholesale price.

creates an additional utility cost$M \geq 0$ for borrowers, because it may negatively affect their relationship with the cooperative, which pays a premium price for milk, and which is owned by fellow farmers.

The lender is a monopolist with cost of capital R_D.[12] The lender chooses a required deposit value D^* to maximize expected profits. Reflecting the regulatory cap on interest rates faced by SACCOs, the gross interest rate that the lender charges to borrowers is capped at R_T. (Empirically, the net interest rate corresponding to R_T is the 1% per month interest rate charged by the SACCO.)

Denote the total cost of repossession to the lender as K.[13] (In the program we examine, farmers were charged a KSh 4,000 repossession fee, but we estimate the full cost of repossession for the lender at KSh 8,500, even excluding intangible costs like the costs of bad publicity and the risk of vandalism, so the empirical case corresponds to $K = 8,500$ and $K_B = 4,000$.)We assume $K_B < K$ as this would reasonably be expected as a property of the optimal contract, since because 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. [14]

Below, we first solve potential borrowers'problems of whether to repay conditional on having borrowed and whether to borrow given the D chosen by the lender. We then solve for the profit maximizing D^* for the lender, given borrower behavior.

3.2 The Borrowers' Problem

We first consider the problem of a borrower deciding whether to repay a loan given the deposit D, their tank valuation θ_i, savings S, and second period income y_i. We then solve backwards

[12]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.

[13]For example, 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.

[14]Moreover, 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.

to the first-period problem of a potential borrower deciding whether to purchase a tank given their wealth and tank valuation.

Proposition 1. *Under the conditions on the distribution of tank valuation assumed earlier, a marginal level of income exists, denoted by $y^R(\theta_i, S, D)$, at which a borrower with valuation θ_i is indifferent between forgoing consumption in order to make the repayment and allowing the tank to be repossessed. y_i^R is strictly decreasing in θ_i and S, and weakly decreasing in D. When D is such that all repossessions result in negative equity, y_i^R is strictly decreasing in D.*[15]

Proof: see appendix.

When choosing whether to repay the loan, the borrower trades off utility from the composite consumption good against utility from the tank. Since utility of consumptionis concave, the cost of foregone consumption from repaying the tank loan is decreasing in second-period resources, and thus S and y. Higher θ makes repayment more attractive. y^R defines a repayment probability that is increasing in S. In general, y^R does not need to be within $[\underline{Y}, \overline{Y}]$ for every (θ_i, S, D) tuple; however our assumptions ensure that there do exist such tuples at which borrowing occurs.

Corollary 2. *For definitely credit-constrained borrowers who have $S = D$, y_i^R is strictly decreasing in the deposit requirement even if negative equity lending does not occur.*

This follows immediately from the fact that y_i^R is decreasing in S. Note that higher D may make the potential credit-constrained borrower worse off overall by constraining c_1, but it increases second period assets, which allows higher c_2. Diminishing marginal utility of consumption then favours repayment once the loan has been made. In the negative equity case, higher S (via D) increases c_2 under repayment (but has no effect on c_2 under repossession), so this effect is even stronger.

[15]Note for this section's propositions that $\theta^R, y_i^R, \theta^*$, and u may fail to be differentiable at $D = D_F$. This is because utility in the case of repossession may not be differentiable with respect to D at this point. Thus this section's proofs all assume $D \neq D_F$. However, all of the propositions still hold at $D = D_F$ in the following sense: because all of the aforementioned functions are continuous at $D = D_F$ and continuously differentiable around $D = D_F$, if a proposition states, for example, that a function f is weakly increasing in D, we have shown that its derivative is non-positive where it exists, and thus there exists some $\epsilon > 0$ such that for all $D \in (D_F - \epsilon, D_F + \epsilon)$, $f(D) \geq f(D_F)$ if $D < D_F$ and $f(D) \leq f(D_F)$ if $D > D_F$.

Having solved for repayment behavior conditional on borrowing and saving, we can now solve for borrowing and saving behavior as functions of D and w.

Proposition 3. *Potential borrowers will borrow if $\theta_i > \theta^*(D, w_i)$, where θ^* is weakly increasing in D for all farmers, strictly increasing in D for some farmers, and decreasing in w_i. Hence, the repossession rate will be:*

$$\rho(D) = \frac{\int_w \int_{\theta^*(D,w)}^{\bar{\theta}} F_Y(y^R(\theta, S, D)) f_\theta(\theta) f_w(w) dw d\theta}{\int_w [1 - F_\theta(\theta^*(D, w))] f_w(w) dw}. \tag{1}$$

Proof: See Appendix.

Potential borrowers compare the expected utility from borrowing to purchase the tank against the expected utility from not borrowing. The expected utility from borrowing depends on the distribution of income draws, and the subsequent optimal choice regarding whether to repay the loan and thus retain the tank. In particular, in any y realisation where borrowers subsequently choose to default on the loan, they would have been better off by not borrowing.

Borrowing to purchase the tank reduces consumption for all income realizations, and potential borrowers thus consider the gains from owning the tank against the cost of foregone consumption. Given the assumptions on the support of the cumulative distribution function $F(\theta_i)$, there will be an interval of wealth levels for which a marginal potential borrower, with valuation $\underline{\theta} < \theta^*(D, wW) < \overline{\theta}$, exists. This borrower is indifferent whether to borrow. Potential borrowers with greater valuations will borrow while those with lower valuations will not. There may be some wealth levels below which even those with $\theta = \bar{\theta}$ do not borrow (and some wealth level above which everyone borrows). The mass of potential borrowers who decide to borrow is given by

$$\tau(D) = 1 - \int_{\underline{w}}^{\overline{w}} F_\theta(\theta^*(D, w)) f_w(w) dw. \tag{2}$$

Proposition 4. *Potential borrowers with $\theta_i > \theta^*(D, w)$ who are definitely credit constrained will have $S = D$, and would be strictly better off with a lower required deposit. Moreover, if repossessions are negative equity, potential borrowers are better off with a lower deposit irrespective of whether they are credit constrained. Trivially, those with $\theta_i < \theta^*(D)$ are indifferent to marginal changes in D since they* *do not borrow.*

Proof: By definition , those who are definitely credit constrained have

$$u'(w_i - D) > R_D \mathbb{E}\left(u'(y_i + R_D D - R_T P)\right) \tag{3}$$

and maximize expected utility by consuming $c_1 = w_i - D$ and $c_2 = y_i + R_D D - R_T P$. To see this, note that $y_i + R_D S - R_T P$ is a borrower's consumption level under repayment, and recall that borrowers have higher period 2 consumption in the case of default than in the case of repayment. Thus $u'(y_i + R_D S - R_T P)$ represents an upper bound on a borrower's marginal period two utility. $u'(y_i + R_D S - R_T P)$ is trivially decreasing in S for $S > 0$. Furthermore $u'(w_i - S)$ is trivially increasing in S for $S \geq w_i$ (and $S \geq D \implies S \geq w_i$). Thus definitely credit constrained borrowers maximize expected utility by setting S=D, and are strictly better off with a lower deposit.

Other potential borrowers with $\theta_i > \theta^*(D, W)$ will be better off with a marginally lower deposit if there are realizations of Y for which they would default and if $D \leq D_F$ (that is, if the repossession is negative-equity), and indifferent otherwise. To see this, note first that under negative-equity repossession, c_2 is decreasing in D since more wealth is seized when D increases. To see that non-credit-constrained borrowers with $\theta_i > \theta^*$ are indifferent to changes in D when default never occurs or is positive equity, note first that unconstrained borrowers who don't default ultimately recover all of $R_D D$ and thus are unaffected by changes in D. Similarly, unconstrained borrowers who *do* default also recover all of $R_D D$ when $D \geq D_F$. The third result, that those who do not borrow are indifferent to marginal changes in the required deposit, trivially follows from the fact that they do not borrow, and thus don't put down a deposit.

3.3 The Lender's Problem

Now consider a profit-maximizing lenders problem of choosing the optimal required deposit D^*. [16] Denote the lenders net profit per customer who repays a loan without a tank repossession as Π_r, equal to the interest paid by the borrower minus the cost of borrowing the capital to finance the loan, $R_D P$.

$$\Pi_r(D) = (R_T - R_D)P \tag{4}$$

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 required deposit and the accrued interest, $R_D D$, sell the repossessed tank for δP, and incur the cost of repossession, K, in addition to the previous outlay on borrowing the capital for the loan, $R_D P$. It will have to return to the borrower any proceeds of the tank sale net of interest and repossession fees, $max\{R_D D + \delta P - R_T P - K_B, 0\}$. Hence, the lender"s profit from a loan, Π_d, if the loan is defaulted upon and the tank is repossessed is

$$\Pi_d(D) = \begin{cases} K_B - K + R_T P - R_D P & \text{if positive equity default} \\ \delta P + R_D D - K - R_D P & \text{if negative equity default} \end{cases} \tag{5}$$

Define the *net loss* that the lender incurs from default as their total profit had the loan been repaid, less their profit under repossession, $L_d(D) = \Pi_r(D) - \Pi_d(D)$ (so positive numbers indicate a relative loss).

$$L_d(D) = \begin{cases} K - K_B & \text{if positive equity default} \\ R_T P + K - \delta P - R_D D & \text{if negative equity default} \end{cases} \tag{6}$$

Let $E(\Pi(D))$ denote expected total profits, which the lender maximizes over D. On the inten-

[16]The SACCO has major market power, so for simplicity we model it as a monopolist. While other lenders serve rural Kenya, the SACCO's unique relationship with the farmers in our sample gives it an effective monopoly on this particular type of loan for dairy farmers in the area.

sive margin, an increase in D will (weakly) reduce tank repossession risk for existing borrowers since borrowers will be less willing to allow tanks to be repossessed if they are required to make a larger deposit. Intuitively, this is because a larger deposit means that they have more resources in period $t = 2$ from which to finance consumption, reducing $u'(c_2)$. For negative equity borrowers, default also falls in D as it involves greater foregone consumption. This is the treatment effect of D. On the extensive margin, an increase in the required 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. This never occurs in our data.

The lender's problem is thus given by

$$\max_D E(\Pi(D)) = \max_D \left\{ \int_{\underline{w}}^{\overline{w}} \int_{\theta^*(D,w)}^{\bar{\theta}} \left[\Pi_r(D) - F(y^R(\theta, S^*(w, D), D)) L_d(D) \right] f_w(w) f_\theta(\theta) d\theta dw \right\} \tag{7}$$

where $\Pi_r(D)$ is the lender's profit per repaid loan and $\int_{\theta^*(D)}^{\bar{\theta}} \left[F(y^R(\theta, S)) \right] f_\theta(\theta) d\theta$ is the amount of tank repossessions for a given level of D and chosen S.

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

$$\begin{aligned} \frac{\partial E(D)}{\partial D} = \int_{\underline{w}}^{\overline{w}} \Bigg[&- \frac{\partial \theta^*}{\partial D} f_\theta(\theta^*) f_w(w) \left[\Pi_r - F(y^R(\theta, S^*, D)) L_d(D^*) \right] \\ &- \left(\int_{\theta^*}^{\bar{\theta}} \frac{\partial F(y^R(\theta, S^*, D))}{\partial D} f_\theta(\theta) f_w(w) d\theta \right) L_d(D^*) \\ &- \left(\int_{\theta^*}^{\bar{\theta}} F(y^R(\theta, S^*, D)) f_\theta f_w(w)(\theta) d\theta \right) L'_d(D^*) \Bigg] dw = 0. \end{aligned} \tag{8}$$

In maximising profit, the lender will not consider the welfare effects of raising the required deposit on inframarginal customers who would have borrowed in any case. Customers who are credit constrained or have negative equity suffer a reduction in utility from an increase in the required deposit, that does not factor into the lender's choice of the required deposit rate. 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 ratio 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.

There are two points at which profits could fail to be continuously differentiable in D. One of these points is the minimal deposit level at which all of the borrowers repay, $\tilde{D}$. Lemma 1 demonstrates that $D^* < \tilde{D}$.

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

Proof: see appendix.

Intuitively, this lemma follows from the fact that if there were zero repossessions, the lender could lower the deposit, increasing the number of borrowers with a negligible increase in the repossession rate. Also note that if the distribution of y were not bounded, then the lemma trivially holds.

The other point at which profits could fail to be continuously differentiable in D is the point, which we will call D_F, at which a borrower's net equity after the resale of a tank is zero. Specifically, D_F is the point at which the deposit plus the resale value of the tank just covers the debt on the tank plus interest and the repossession fee, K_B. 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 changing the probability of tank repossession. By Lemma 1, profits are continuously differentiable with respect to D over the interval $[0, \tilde{D})$ except at D_F.

Thus for $D^* \neq D_F$, 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 infra-marginal 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.[17]

Proposition 5. *If the profit-maximizing D^* is not D_F, (i.e., if $R_D D^* + \delta P - K_B - R_T P \neq 0$), then reducing the deposit requirement from the profit maximising level D^* increases social welfare.*

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

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

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

If $R_D D + \delta P - R_T P - K_B \neq 0$ (i.e., $D \neq D_F$), then D^* is characterized by the lender's FOC, which implies $\frac{\partial E(\Pi(D))}{\partial D} = 0$. As we showed before, definitely credit-constrained inframarginal borrowers strictly prefer lower deposits, and other inframarginal borrowers weakly prefer lower deposits: $\frac{\partial \mathbb{U}_{total}(D)}{\partial D} < 0$. Given the assumptions on the support of w and θ, there will be a nonzero-measure group of inframarginal borrowers who are definitely credit constrained. Potential borrowers who do not borrow will be indifferent to changes in D. Hence the derivative of the social welfare with respect to D is negative:

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

[17]From the standpoint of an unconstrained social planner who seeks to maximize social welfare, the first best would be to allocate tanks to every farmer who has a sufficiently high valuation. Repossessions consume resources, so would never take place. This could be implemented by setting required deposits to zero, and only allowing high valuation farmers to borrow. Further, on account of risk aversion through concave $u(c)$ it is optimal for farmers to be fully insured against income shocks. Consumption utility then becomes deterministic.

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 potential borrowers 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 borrower welfare into account will set a strictly lower D than would a profit-maximizing lender. $\square$

Consider for a moment the empirically relevant special case, where the deposit plus the resale value of the tank is great enough that the borrower has positive equity. Hence, in this case L_d is not a function of D, thus $L_d'(D) = 0$ and the FOC simplifies and can be written as:

$$\frac{\int_{\underline{w}}^{\overline{w}} \frac{\partial \theta^*}{\partial D} f_\theta(\theta^*) f_w(w) dw}{\int_{\underline{w}}^{\overline{w}} \left[\frac{\partial \theta^*}{\partial D} F(y^R(\theta^*, S^*)) f_\theta(\theta^*) - \int_{\theta^*}^{\bar{\theta}} \frac{\partial F(y^R(\theta, S^*))}{\partial D} f_\theta(\theta) d\theta \right] f_w(w) dw} = \frac{L_d(D^*)}{\Pi_r} = \frac{K - K_B}{(R_T - R_D)P}. \quad (9)$$

Here, the left hand side is the ratio of marginal borrowers to marginal tank repossessions. The marginal tank repossession term consists of two components; marginal borrowers having positive default probability, and inframarginal borrowers having increased default probability. In the empirical section we will measure this ratio. At the optimal deposit set by the lender, this ratio equals the ratio of the net costs of a tank repossession to the profits from a successful loan. $L_d > P_r$ and thus this ratio must exceed one, since otherwise even loans that are defaulted upon are profitable overall.

3.4 Discussion

We have treated the distribution of income as independent across potential borrowers, 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 borrower-specific shock and the common shock is observable, but idiosyncratic shocks are private information for borrowers. In this case, requiring all borrowers to be insured against aggregate risk would reduce repossessions by addressing the moral hazard that arises if borrowers 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 borrowers 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.The assumptions of the model ensure that there are farmers with low enough tank valuations that they choose not to borrow but enough initial wealth that they would not be credit constrained if they did borrow. They also ensure that there are farmers with too little initial wealth to borrow, but high enough tank valuation that they would borrow if they were not credit constrained. Imagine farmers could perfectly contract with each other in the sense of being able to observe each other's initial wealth, tank valuations, and income, and fully enforce all contracts. Then regardless of whether the lender offers a formal guarantor contract, high-wealth, low-valuation farmers would act as guarantors to low-wealth, high-valuation farmers. In the case that the lender does not offer a guarantor contract, de facto guarantors could lend low-wealth borrowers money to pay down their deposit. Thus the existence of a guarantor contract from the lender will not affect loan uptake. Similarly, if farmers cannot contract with each other independent of the existence of a formal guarantor contract, then loan uptake will be the same with or without such a contract.

On the other hand, if the existence of a formal guarantor contract improves farmers' ability to contract with each other, then such an arrangement will affect outcomes. Formal guarantor agreements could improve farmers' ability to contract with each other if, for example, informal borrowers had the option to default on informal lenders by choosing to use their loan funds for something other than purchasing the tank (i.e, further increasing first-period consumption), and if lenders were then unable to extract repayment in the second period. One scenario in which this would be the case is one in which would-be guarantors were concerned that borrowers might ask for "loans" only to abscond with their borrowed funds and move out of town. This option would be rendered impossible by the existence of a formal guarantor contract which would ensure that the informal borrower actually puts the guarantor's money into buying the tank. Thus formal contracts would incentivize repayment (and mitigate adverse selection of informal borrowers with no intention of repaying) by introducing the cost of a lost tank for those who default.

However, while formal guarantor contracts impact *individual* outcomes in this intermediate case, they need not necessarily increase total demand for loans in general equilibrium. High-wealth, low-valuation farmers who are near-indifferent toward borrowing but do borrow in the case of no guarantor contracts may choose not to borrow if it is possible for them to act as guarantors. Such farmers may prefer to act as guarantors for high-valuation low-wealth borrowers, and in doing so may lose enough period-one wealth to render borrowing no longer worthwhile. The net effect could be that all borrowers who enter the market when guarantor contracts are introduced are offset by guarantors leaving the market, or even that more guarantors leave the market than borrowers enter.

Thus it is an empirical question whether guarantor contracts impact outcomes, as theory would predict different outcomes depending on the nature of contracting in a given empirical context. In the case that informal lending is either always possible or never possible, formal guarantor contracts will not have an impact, but in the intermediate case they might. Our empirical results indicate that some borrowers are indeed credit constrained, and thus it must not be the case that informal lending occurs as described above. Our finding that the introduction of guarantors does not affect loan take up suggests that our experimental environment is not described by this intermediate case. The scenario described above in which guarantor contracts don't impact aggregate outcomes in the intermediate case seems unlikely to correspond to our empirical context. The reason for this is that only a small subset of farmers were offered loans with guarantor contracts. Thus it is likely that for any borrower who might choose to be a guarantor instead of borrowing, there is a non-borrower with lower tank valuation and equal or higher wealth. These non-borrowers gain more on net from acting as a guarantor (since they don't give up the opportunity to borrow a tank), and thus can offer more favorable terms. Thus it is likely the case that none of the guarantors in our sample would have borrowed had they not acted as guarantors.

The 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 ratio empirically, so the details of exactly what generates the observed borrower 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.

Note that some borrowers 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 borrower does not fully internalise the repossession costs if they have negative equity, which occurs if $R_D S$ plus the resale value of the tank δP is less than $R_T P + K_B$. A greater deposit could potentially ameliorate the moral hazard problem and reduce tank repossession.

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.[18] The price of the tank to the farmers, denoted P 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.[19] 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

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

[19] 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.

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 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.[20]

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.[21] 460 farmers took out loans..[22]

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

[20] 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.

[21] 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.

[22] 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.

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,[23] while detailed production data was elicited from households in the 4% deposit group and the 100% cash collateralized group.[24] Finally, administrative data from the dairy cooperative was used to construct indicators of loan recovery, repossession, late payment collection actions[25], 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.

[23]Specifically, 1,699 households were interviewed in September 2011: 1,710 in February 2012; and 1,660 in May 2012.
[24]Data was collected from 901 respondents in 2011, and from 863 respondents in February 2012.
[25]E.g. receipt of a letter warning of pending default or reclamation of security deposit

5.2 Empirical Approach

Empirical specifications typically take the form:

$$y_i = \alpha + \beta_A A_i + \beta_D^M D_i + \beta_D^W D_i^W + \beta_G^M G_i + \beta_G^W G_i^W + \varepsilon_i \tag{10}$$

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, 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 $1 - \int_{\underline{w}}^{\overline{w}} F(\theta^*(D,w)) f_w(w) dw$ and the repossession rate corresponds to $\frac{\int_w \int_{\theta^*(D,w)}^{\bar{\theta}} F_Y(y^R(\theta,S,D)) f_\theta(\theta) f_w(w) dw d\theta}{\int_w [1 - F_\theta(\theta^*(D,w))] f_w(w) dw}$. 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 $\theta^*(D, w_i)$ while the treatment effect corresponds to changes in $y^R(\theta, S, D)$.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

$$\frac{\rho(6,000) - \rho(1,000)}{\frac{\tau(6{,}000)-\tau(1{,}000)}{\tau(1{,}000)}} \tag{11}$$

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 $y^R(D, \theta, S)$ falls for some borrowers and is unchanged for others.. The effect of moving from $D = KSh\, 6,000$ to $D = KSh\, 1,000$ corresponds to $\rho(6,000) - \rho(1,000)$ 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.[26]

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.)

[26]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.

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.

These results also are consistent with our model, as they support the hypothesis that potential guarantors face the same alternative investment opportunities as do farmers in our sample.

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 non-borrowers in all experimental arms.

Of the 84 possible pair-wise comparisons,[27] 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

[27] $3! = 6$ pairs for each of 14 variables.

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.[28] 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.

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.

[28] 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]).

7.1 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.[29] 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).[30] 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

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

[30] 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.

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 Pearson, 1934).[31]

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 reposses-

[31] 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 $(1-p)^n = \alpha$

sion, 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.[32]

7.2 Calibration and Change in SACCO Policy Following the Program

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. 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%, 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 repossession, we cannot reject the hypothesis of an underlying increase in tank repossession of up to 0.32 percent with 75% asset collateralization.

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

Since the model finds that borrower welfare is improved with a lower deposit requirement, and the SACCO's behavior (along with our findings on repossessions) suggest that this lower deposit was objective-maximizing for the SACCO, the results indicate that moving from 100% cash collateralization to 75% asset collateralization was welfare-improving.[33]

Given that the SACCO did not choose to continue offering 96%-asset-collateralization loans, it is not clear from observation alone whether doing so would have been socially optimal. 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 reducing the borrowing requirement to 4% might have benefited borrowers, it would have reduced overall profits and thus harmed non-borrowers, which would include the median voter in the SACCO.

To address the question of whether further lowering the deposit rate would have been socially optimal, we turn to a calibration of our model. While the model is stylized, and not meant to capture all features of the setting we examine, a rough calibration based on our 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. 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 $\rho(1,000) = 0.007\%$, and zero for 25% loans (Table 5, column 2), so $\rho(6,000) = 0\%$. The take up rate for 4% deposit loans is 41.89%. For 25% deposit loans, the combined sample take up is 23.93%. Thus $\frac{\tau(6,000)-\tau(1,000))dw}{\tau(6,000)} = (41.89-23.93)/41.89 = 42.9\%$. In other words, 42.9% of those

[33]It is possible, however, that the 700 KSh fee introduced by the SACCO, which may have been essential to making the lower deposit requirement profitable, outweighed the benefits to borrowers from a lower deposit requirement.

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. 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 requirement will be lower than the profit-maximizing level. We find that despite lower SACCO profits, for reasonable parameter values, 96% asset collateralization would be socially preferable to 75% asset collateralization. In particular, given the calibrated values of other parameters, we estimate that gains to farmers from lowering the deposit requirement would exceed losses to the SACCO as long as farmers discount the future at a rate greater than 2.2% yearly. Unlike a profit-maximizing lender, a social planner will also take into account the benefits to the inframarginal borrowers of a lower deposit requirement. It should be noted that while the SACCO (and the lender in the model) have monopoly or near-monopoly power, this wedge between the social and private optimum is separate from the typical underproduction of goods in a monopolistic market. The calibration only considers impacts on *inframarginal* borrowers, and does not account for the welfare provided by the increased quantity of tank purchases resulting from a lower deposit requirement.

To see that 96% asset collateralization would be socially preferable to 75% collateralization, we estimate the effect of a lower deposit on inframarginal borrowers' welfare. For the purposes of the calibration, we will assume that borrower utility takes a CRRA form and–following Laibson et al (2017)–we will assume an elasticity of intertemporal substitution of .995. Laibson et al. (2017) find a discount rate of 10.7%, yearly and we use this value in our estimates of the total welfare gain from lowering the deposit. Note that this 10.7% rate is substantially higher than the estimated 2.2% minimum rate above which a lower deposit is socially preferable. Results are similar to those presented here for a wide range of alternative parameter assumptions (see appendix B for details).[34] We assume borrowers hold no liquid assets, so that all consumption comes out of a monthly income, which is constant across months at the empirically observed mean consumption level of KSh 10,000.[35] Borrowers save up for the deposit at a constant per-month rate. Borrowers determine how many months to spend saving for the deposit, and conditional on this choice, set per-month savings such that they have saved exactly the amount required for the deposit requirement at the end of the last month of saving. Since borrowers receive the tank when they pay off the deposit, this optimization involves a trade off between the consumption-smoothing benefits of saving over a long period and the discounting benefits of waiting only a short period to receive a tank. For more details on the calibration's framework, see appendix A.

The primary benefit to borrowers of a lower deposit is earlier tank consumption.[36] Under

[34]Laibson et al (2017) estimate both exponential and quasi-hyperbolic discount functions. We use the parameters estimated for exponential discounters. For a review of estimates on intertemporal utility parameters, see Frederick et al. (2002). Gourinchas and Parker (2002) estimate intertemporal utility parameters using an approach similar to that used in Laibson et al.

[35]Farmers in our sample do hold wealth beyond labor income (as reflected in the model), but it is largely in the form of illiquid assets such as cows and land. Since these illiquid assets are unlikely to affect how borrowers respond to and benefit from a lower deposit level, the calibration makes the simplifying assumption that all consumption comes from labor income.

[36]There are two other effects on borrower welfare of lowering deposit requirements, but both are minor. One is that borrowers pay more in interest when the deposit is lower, since this results in a higher loan principal. This effect trivially pushes against the benefit of earlier tank consumption, lowering welfare under the 1000 KSh deposit level. The other effect is that–partly because of the assumption that borrowers smooth saving for the deposit perfectly over different months–borrowers have different consumption paths under the two deposit levels. The sign of this effect is theoretically ambiguous, as consumption is lowered at some points when the deposit requirement is lowered, and raised at others.

the assumptions of the calibration, borrowers spend nine months saving for the tank when the deposit requirement is 6,000 KSh, and two months saving when the deposit requirement is 1,000 KSh. The welfare gain to each inframarginal borrower from lowering the deposit from 25% to 4% is KSh 1,260, indicating a mean per-borrower welfare gain across all borrowers of $.57 * 1,260 = 718.3KSh$, since 57% of borrowers are inframarginal. Holding borrower elasticity of intertemporal substitution constant (at .995), the total benefits to borrowers from lowering the deposit from 6000 KSh to 1000 KSh exceed the total costs to the SACCO so long as borrowers discount the future by more than 2.2% yearly. .

An additional calibration, based on a model in which farmers have alternative investments to holding deposits with the SACCO, also suggests the 4% deposit requirement would be socially preferable to the 25% requirement. If the alternative investments yield higher returns than deposits with the SACCO, tying up funds in the tank deposit presents an opportunity cost. We omit the details here, but it is relatively straightforward to calculate the rate of return at which the cost to borrowers of tying up an additional 5000 KSh in the loan deposit outweighs the cost to the SACCO of the additional defaults introduced by lowering the requirement by 5000 KSh. The result is that, omitting consumption smoothing considerations, the opportunity cost to borrowers outweighs the cost to the SACCO when alternative investments yield an annual nominal return more than 13 percent. 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 et. al. (2008); Kremer et. al. (2011)) suggests that the rate of return available to borrowers on other projects is far in excess of this cutoff value of nominal returns.

7.3 Late Payment

For 456 borrowers in the original sample, we have complete repayment data [37]. Among these borrowers, we find strong evidence across multiple measures of late payment (e.g., late repayment during the loan cycle, late repayment at the end of cycle, size of late balance) that deposi-

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

tors under the 25% and 4% deposit loans are more likely to pay late than those under the 100% cash collateralized loans. 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.

One other striking feature of the data is that early repayment was common. 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.

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). [38] 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 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

[38] 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.

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 Out of Sample Tests

To test the validity of our results, we conducted a second out-of-sample test in Kenya after the initial study. We observed similar results in the out-of-sample test. The lender has extended the program, using its own resources, which also indicates that the program has not led to high default rates.

A similar pilot program was implemented by the J-PAL Africa policy team in Rwanda. In the first phase, 43 out of about 160 farmers took up the loan, with only one default. Thirteen SACCOs have chosen to implement similar programs without subsidies.

10 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, if borrowers discounted the future with annual rate less than .987, then the profit-maximizing borrowing requirement 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.[39]

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

[39]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.

with a 4% down payment.[40]

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. [41]

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 -

[40] 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 ratio.

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

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, 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.

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A Proofs for the Model Section

Proposition 1.

Under the conditions on the distribution of tank valuation assumed earlier, a marginal level of income exists, denoted by $y^R(\theta_i, S, D)$, at which a borrower with valuation θ_i is indifferent between forgoing consumption in order to make the repayment and allowing the tank to be repossessed. y_i^R is decreasing in all of its arguments.

Proof. If the borrower repays the lender, her second-period utility is

$$U_{2,r}(y_i, S; \theta_i) = \theta_i + u(y_i + R_D S - R_T P), \tag{12}$$

that is, the benefit of the tank, θ_i, plus the consumption utility from resources remaining once the loan principal and interest $R_T P$ are repaid. Consumption is financed from the remainder of the gross returns from savings and the income draw.

To derive the utility of a borrower who does not repay the loan and allows the tank to be repossessed, first consider the net proceeds the borrower receives from the sale of the tank. In the event of repossession, a borrower will receive their net equity in the tank (from the lender's point of view) if it is positive and will lose the required deposit if their net equity is negative. The net equity of the borrower is equal to the total value of the tank and the required deposit, $R_D D + \delta P$, minus the total claims of the lender in the event of default, $R_T P + K_B$. Hence, in the event of default, the borrower faces a financial cost from default of $\min\{R_T P + K_B, R_D D + \delta P\}$. Since the borrower"s assets before repossession have value $R_D S + \delta P$, a defaulting borrower receives net proceeds from the first period of $\max\{R_D S - (R_T - \delta)P - K_B, R_D(S - D)\}$, and has total second-period utility of

$$U_{2,d}(y_i, S, D; \theta_i) = u(\max\{y_i + R_D S + \delta P - R_T P - K_B, y_i + R_D(S - D)\}) - M \tag{13}$$

where the final term captures the disutility from harming their relationship with the SACCO M. Consumption is financed by the period two endowment y_i and any net proceeds from the sale of the tank (and any non-deposit savings).

Loan defaults only occur when low income is realized, since high-income borrowers will have a reduced marginal utility of consumption and thus prefer to repay the loan, and potential borrowers will not borrow if they know that they will allow the tank to be repossessed for all income realizations.[42] Note also that whether any eventuating default would be positive or negative equity is determined prior to and independently of the period two income draw, depending only on whether $\delta P + R_D D \geq R_T P + K_B$.

Comparing the utilities from repayment and default yields the condition for repossession, conditional on borrowing at $t = 1$. A borrower will only default upon the loanand allow the tank to be repossessed if she earns low enough income that the utility from defaulting exceeds

[42] Recall that the the borrower receives no utility benefit from the tank if it is repossessed, but still incurs the repossession fee.

the utility from repayment:

$$U_{2,repossession}(y_i, S; \theta_i) > U_{2,repay}(y_i, S; \theta_i). \tag{14}$$

Under the conditions on the distribution of tank valuation assumed earlier, a marginal level of income exists, denoted by $y^R(\theta_i, S, D)$, at which a borrower with valuation θ_i is indifferent between repaying the loan and allowing the tank to be repossessed. Since $u'(c)$ is decreasing, and default gives higher consumption, repayment is preferred at any higher y_i.

First consider the case where D is such that any loan default involves positive equity.

$$\exists\, y^R : \theta_i + u(y^R + R_D S - R_T P) = u(y^R + R_D S + \delta P - R_T P - K_B) - M \tag{15}$$

Clearly, higher θ_i allows higher $u(c_d) - u(c_r)$; for a given increment of c this requires lower y^R. Formally, by total differentiation:

$$d\theta_i + \left(u'(c_{2,r}) - u'(c_{2,d})\right)(dy^R + R_D dS) = 0 \tag{16}$$

$$\Rightarrow \frac{\partial y^R}{\partial \theta_i} = -\frac{1}{u'(c_{2,r}) - u'(c_{2,d})} < 0 \tag{17}$$

$$\Rightarrow \frac{\partial y^R}{\partial S} = -R_D < 0 \tag{18}$$

Separately, in the case where negative equity repossession can occur,

$$\exists y^R : \theta_i + u(y^R + R_D S - R_T P) = u(y^R + R_D(S - D)) - M \tag{19}$$

By total differentiation:

$$d\theta_i + u'(c_{2,r})(dy^R + R_D dS) - u'(c_{2,d})(dy^R + R_D(dS - dD)) = 0 \tag{20}$$

$$\Rightarrow \frac{\partial y^R}{\partial \theta_i} = -\frac{1}{u'(c_{2,r}) - u'(c_{2,d})} < 0 \tag{21}$$

$$\Rightarrow \frac{dy^R}{dS} = -R_D < 0 \tag{22}$$

$$\Rightarrow \frac{dy^R}{dD} = -\frac{u'(c_{2,d})}{u'(c_{2,r}) - u'(c_{2,d})} R_D < 0 \tag{23}$$

These results reflects that, for a borrower with given θ_i who has positive equity, the decision to repay only depends on their wealth, and thus higher S reduces y^R. In the negative equity case,the direct effect of D (holding S constant) is to decrease c_2 under default, again reducing y^R. Higher θ_i increases the benefits of repayment, and thus justifies incurring the greater foregone consumption utility associated with lower y_i. □

Proposition 3. *Potential borrowers will borrow if $\theta_i > \theta^*(D, w_i)$, where θ^* is weakly increasing in D for all farmers, strictly increasing in D for some farmers, and decreasing in w_i. Hence, the repossession rate will be:*

$$\frac{\int_w \int_{\theta^*(D,w)}^{\bar{\theta}} F_Y(y^R(\theta, S, D)) f_\theta(\theta) f_w(w) d\theta dw}{\int_w [1 - F_\theta(\theta^*(D))] f_w(w) dw}. \tag{24}$$

Proof. At period $t = 1$, potential borrowers i will borrow if expected utility from not borrowing is lower than expected utility from borrowing. The utility potential borrowers receive if they do not borrow, denoted as $\bar{U}$, is equal to their consumption utility across the two periods $u(c_1^0) + u(c_2^0)$ where second-period consumption is $c_2^0 = (w - c_1^0)R_D + y_i$. This is evaluated at the consumption profile that maximises expected utility, characterised by the Euler equation $u'(c_1^0) = R_D \mathbb{E}(u'(c_2^0))$.

Borrowers, knowing their θ_i, will allow their tanks to be repossessed if they have a low income realization, $y_i \leq y^R(\theta_i, D)$. 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 default, $U_d(y_i, D; \theta_i)$, and that lead to keeping the tank, $U_r(y_i, D; \theta_i)$. This will exceed the expected utility from not borrowing, and thus the individual will choose a savings amountt S (and thus a c_1) and borrow, if

$$\max_{S \geq D} \left(\int_{\underline{Y}}^{y_i^R} U_d(y_i, S, D; \theta_i, w_i) f_Y(y_i) dy_i + \int_{y_i^R}^{\bar{Y}} U_r(y_i, S, D; \theta_i, w_i) f_Y(y_i) dy_i \right) \geq U(\bar{w_i}). \tag{25}$$

Note that the value $U_d(y_i, S, D; \theta_i, w_i)$ depends on whether D is sufficiently large to preclude negative equity repossession.

Since borrowers who do not value tank ownership are strictly worse of borrowing, there exists a marginal tank valuation, denoted by $\theta^*(D, w) \in [0, \infty)$, where a potential borrower with wealth w would beindifferent regarding whether to borrow. $\theta^*(D, w)$ need not be within the support of θ for all w, but under our assumptions, for every $D \in [0, P]$ there is a range of w for which $\theta^*(D, w) \in [\underline{\theta}, \overline{\theta}]$. Higher valued potential borrowers will borrow while lower valued potential borrowers will not. Thus, the mass of potential borrowers with a fixed w who borrow is given by $1 - F_\theta(\theta^*(D, w))$, with the mass of defaults given by $\int_{\theta^*(D,w)}^{\bar{\theta}} F_Y(y^R(\theta, S) f_\theta(\theta) d\theta$ Integrating over the distribution of w gives the population default rate.

It is useful to consider how the borrowing decision depends on the deposit requirement for two different classes of borrowers. The first are agents who have initial wealth high enough that they can deposit D without being credit constrained. These borrowers accordingly choose $S > D$ to satisfy their Euler equation across the two periods, equalizing the marginal utility of consumption in the first period with the expected marginal benefit from second period resources. When D is such that any repossession is positive equity, changes in D have no effect on the Euler equation and thus S. However, where negative equity repossession is possible, higher D reduces c_2 under repossession. This both increases the expected marginal utility of second period income, leading to higher S being chosen conditional on borrowing, and makes borrowing to purchase the tank less attractive, increasing θ^*. Thus for the borrowers who are not credit constrained, it is trivial that θ^* is (weakly) increasing in D. Higher θ_i borrowers combined with higher S being chosen given θ_i trivially yields a lower repossession rate for this group.

The second group are borrowers who are credit-constrained, and thus conditional upon borrowing set $S = D$. To see how the borrowing decision depends on the deposit requirement, take the derivative of equation (25) at θ^* with respect to D (notice that the terms that correspond to the derivatives of y_i^R with respect to S in the integral endpoints cancel out by the Envelope Theorem). As before, a change in D :

$$\int_{\underline{Y}}^{y^R} \left[\frac{\partial U_d}{\partial S} + \frac{\partial U_d}{\partial \theta} \frac{\partial \theta^*}{\partial D} \right] f_Y(y_i) dy_i + \int_{y^R}^{\bar{Y}} \left[\frac{\partial U_r}{\partial S} + \frac{\partial U_r}{\partial \theta} \frac{\partial \theta^*}{\partial D} \right] f_Y(y_i) dy_i = 0. \tag{26}$$

Then,

$$\frac{\partial \theta^*}{\partial D} = - \frac{\int_{\underline{Y}}^{y^R} \frac{\partial U_d}{\partial S} f_Y(y_i) dy_i + \int_{Y^R}^{\bar{Y}} \frac{\partial U_r}{\partial S} f_Y(y_i) dy_i}{\int_{\underline{Y}}^{y^R} \frac{\partial U_d}{\partial \theta} f_Y(y_i) dy_i + \int_{Y^R}^{\bar{Y}} \frac{\partial U_r}{\partial \theta} f_Y(y_i) dy_i} = - \frac{\int_{\underline{Y}}^{y^R} \frac{\partial U_d}{\partial S} f_Y(y_i) dy_i + \int_{Y^R}^{\bar{Y}} \frac{\partial U_r}{\partial S} f_Y(y_i) dy_i}{\int_{Y^R}^{\bar{Y}} \frac{\partial U_r}{\partial \theta} f_Y(y_i) dy_i} > 0 \tag{27}$$

Since credit constrained borrowers are being considered, the numerator is positive by definition for every individual. Further, by virtue of being credit constrained, for fixed w, c_1 is constant in θ. For a given (D, y_i) pair, second period utility when defaulting is constant in θ, while second period utility from repayment is strictly higher in θ. Thus the envelope of the two, and hence the denominator, is strictly higher in θ. This gives the unsurprising result that when the deposit becomes more costly in terms of hindering consumption smoothing, the potential borrowers that substitute to not borrowing are those who gain the lowest utility from possessing the tank.

For a fixed w, the repossession rate is decreasing in the deposit requirement D, because θ^* is increasing in D (adverse selection) and y^R is decreasing in D (moral hazard). □

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

Proof. Assume for contradiction that D^* is such that the overall probability of repossession is zero.

Let $\mathbb{P}(D, w)$ denote the probability of an individual with initial wealth level w borrowing and defaulting when the deposit requirement is D. Let Ω_0 denote the set of all w such that repossession occurs with nonzero probability for $D = D^*$. Recalling that we have assumed the probability of repossession is zero when the deposit level is D^*, we have

$$0 = \int_{\underline{w}}^{\overline{w}} \mathbb{P}(D^*, w) dw \tag{28}$$

$$= \int_{\Omega_0} \mathbb{P}(D^*, w) dF_w \tag{29}$$

By definition, for any $w \in \Omega_0$,

$$\mathbb{P}(D^*, w) > 0.$$

Thus

$$\begin{aligned}\int_{\Omega_0} \mathbb{P}(D^*, w) dF_w = 0 \\ &\implies \mu(\Omega_0) = 0 \\ &\implies \mu(\Omega_0^c) = 1.\end{aligned}$$

Note that Ω_0^c, the complement of Ω_0, is the set of all w such that $\mathbb{P}(D^*, w) = 0/$

Recall that the derivative of expected profit with respect to the deposit ratio (for $D \neq D_F$) is

$$\begin{aligned}\frac{\partial E(\Pi(D))}{\partial D} = \int_{\underline{w}}^{\overline{w}} \Bigg[&- \frac{\partial \theta^*}{\partial D} f_\theta(\theta^*) f_w(w) \left(\Pi_r - F(y^R(\theta, S^*(w, D), D)) L_d(D^*)\right) \\ &- \left(\int_{\theta^*}^{\bar{\theta}} \frac{\partial F(y^R(\theta, S^*, D))}{\partial D} f_\theta(\theta) f_w(w) d\theta \right) L_d(D^*) \\ &- \left(\int_{\theta^*}^{\bar{\theta}} F(y^R(\theta, S^*, D)) f_\theta f_w(w)(\theta) d\theta \right) L_d'(D^*) \Bigg] dw \quad (30)\end{aligned}$$

By the fact that Ω_0 has measure zero, this is equal to

$$\begin{aligned}\int_{\Omega_0^c} \Bigg[&- \frac{\partial \theta^*}{\partial D} f_\theta(\theta^*) \left(\Pi_r - F(y^R(\theta, S^*(w, D), D)) L_d(D^*)\right) \\ &- \left(\int_{\theta^*}^{\bar{\theta}} \frac{\partial F(y^R(\theta, S^*, D))}{\partial D} f_\theta(\theta) d\theta \right) L_d(D^*) \\ &- \left(\int_{\theta^*}^{\bar{\theta}} F(y^R(\theta, S^*, D)) f_\theta(\theta) d\theta \right) L_d'(D^*) \Bigg] dF_w \quad (31)\end{aligned}$$

When $\mathbb{P}(D^*, w) = 0$,, by definition $F(y^R(\theta, S*, D) = 0$ for all $\theta > \theta^*(D^*)$. Since y^R is weakly decreasing in D, this implies that $\frac{\partial F(y^R(\theta, S^*, D))}{\partial D} = 0$. Thus

$$\int_{\Omega_0^c} - \left(\int_{\theta^*}^{\bar{\theta}} \frac{\partial F(y^R(\theta, S^*, D))}{\partial D} f_\theta(\theta) d\theta \right) L_d(D^*) dF_w \quad (32)$$

$$= \int_{\Omega_0^c} - \left(\int_{\theta^*}^{\bar{\theta}} F(y^R(\theta, S^*, D)) f_\theta(\theta) d\theta \right) L_d'(D^*) dF_w \quad (33)$$

$$= 0. \quad (34)$$

So

$$\frac{\partial E(D)}{\partial D} = \int_{\Omega_0^c} -\frac{\partial \theta^*}{\partial D} f_\theta(\theta^*) \left(\Pi_r - F(y^R(\theta, S^*(w,D), D))L_d(D^*)\right) dF_w \tag{35}$$

$$= \int_{\Omega_0^c} -\frac{\partial \theta^*}{\partial D} f_\theta(\theta^*)\Pi_r dF_w \tag{36}$$

By assumption, there exists a range of w for which $\theta^* \in [\underline{\theta}, \overline{\theta}]$, and for w in this range, $\frac{\partial \theta^*}{\partial D} > 0$. Since Ω_0^c has measure one, its intersection with this range has nonzero measure, and thus

$$\frac{\partial E(D^*)}{\partial D} = \int_{\Omega_0^c} -\frac{\partial \theta^*}{\partial D} f_\theta(\theta^*) P_r dF_w < 0,$$

and profit is not maximized. By the continuity of $E(\Pi(D))$, and the mean value theorem, this implies that profit is also not maximized at $D = D_F$. □

Appendix B: Calibration Framework

We use the following framework to calibrate the model.

As stated in the body of the paper, borrowers are assumed to hold no liquid assets, so that all consumption comes out of monthly income, which is constant across months at the empirically observed mean consumption level of KSh 10,000. Given a time frame for saving for the deposit, borrowers save a constant per-month amount. So if, for example, a borrower were to save up for a 6,000 KSh deposit over four months at gross interest rate R, she would save x KSh each month, where x satisfies $R^3x + R^2x + Rx + x = 6000$. Given this savings pattern, borrowers select an optimal number of months to spend saving for the deposit, weighing consumption-smoothing considerations against discounting of tank utility. At the end of the month in which a borrower pays the deposit, she receives the loan, buys the tank, and begin paying off the remaining principal on the loan. The loan is paid back in monthly installments of KSh 1,000 plus interest, which is charged on a declining balance. We assume that in every period, borrowers consume all income that is not used to make loan payments. Utility is CRRA and discounting is exponential with monthly discount factor δ. We use parameters estimated in Laibson, Maxted, Repetto, and Tobacman (2017): annual discount factor .893 (this translates to a monthly discount factor $\delta = .9906$) and elasticity of intertemporal substitution of .995 ($\theta = 1.005$).

As a simplification, all contracted loan payments are treated as if they were given in real terms. For example, regardless of how long a borrower spends saving up for a deposit, each month's loan repayment is equivalent to 1,000 period-one KSh. The nominal 1% monthly interest payments on the loan are adjusted to a real interest rate using an annual inflation rate of 10%, yielding a real interest rate of 2.68% annual. Similarly, we calculate the real interest earned on borrowers' savings using the 3% quarterly nominal interest rate payed out by the SACCO on cash deposits, yielding a 2.55% annual rate. The findings of the calibration are robust to other reasonable assumptions on the real values corresponding to the nominally-defined loan payments.[43]

Thus a borrower's utility is given by

$$\max_{i_{deposit} \in \{0,1,2,...i_{final}\}} \Bigg(\sum_{i=0}^{i_{deposit}} \delta^i u(10,000 - x(Deposit, i_{deposit})) + \delta^{i_{deposit}} v_{tank} + \\ \sum_{i=i_{deposit}+1}^{i_{payment}} \delta^i u(10,000 - (1,000 + interest)) + \sum_{i_{payment}+1}^{i_{final}} u(10,000) \Bigg). \quad (37)$$

In the above equation, $i_{deposit}$ and $i_{payment}$ denote the months in which the deposit is paid and the loan repayment is completed, respectively. v_{tank} denotes the utility value of the tank. We set v_{tank} to the minimum tank valuation needed for a farmer to prefer borrowing with a 6,000 KSh deposit requirement to not borrowing at all. Thus v_{tank} is a lower bound on the tank valuation of all inframarginal borrowers. $x(Deposit, i_{deposit})$ satisfies, for a given deposit requirement and window of time spent saving up for the tank,

$$x \sum_{i=0}^{i_{deposit}} 1.0021^i = Deposit. \quad (38)$$

$interest = .022[24,000 - Deposit - 1000(i - (i_{deposit} + 1))]$ denotes the declining-balance interest payment in period i. The function u denotes a standard CRRA utility function, $u(y) = \frac{y^{1-\theta}-1}{1-\theta}$.

The code for the calibration is built around finding zeroes of a "Utility with Optimization" function. The "Utility with Optimization" function (described in detail below), accepts utility parameters (θ and δ), a deposit requirement, and a variable p which corresponds to extra period-one cash on hand. This p variable is used to calculate the welfare value of a lower deposit. Given these parameters, "Utility with Optimization" returns the utility of a tank borrower who optimizes the amount of time she spends saving up for the deposit, and who values the tank at the minimum amount, v_{tank}, described above. To calculate the welfare value of a lower deposit, we solve for p in

$$f(1.005, .9906, 6000, p) = f(1.005, .9906, 1000, 0), \quad (39)$$

where f is the "Utility with Optimization" function. To find the maximum δ such that the gains from lowering the deposit outweigh the costs, we hold p fixed at the cost-per-borrower of defaults at the lower deposit level ($\frac{73}{.57}$), and solve

$$f(\theta, \delta, 6,000, p) = f(\theta, \delta, 1,000, 0). \quad (40)$$

The function itself is build as a nested sequence of three functions: tank value, utility given a saving window, and utility with optimization, which are described below.

[43] Details of alternative assumptions considered are available on request.

Tank Value

We first calculate the lower bound on tank valuation (in utility terms) for inframarginal borrowers by finding the tank value that makes farmers indifferent toward borrowing at the 6,000 KSh deposit requirement. The "Tank Value" function receives calibration parameters (θ and δ) and returns this lower bound v_{tank} on tank valuation. "Tank Value" first involves calculating farmer utility conditional on not borrowing, given by

$$u_{noborrow} = \sum_{i=0}^{20} \delta^i u(10,000). \tag{41}$$

We calculate utility over a 21-month window because this is the time period over which the borrower is paying for the tank, and thus the only period over which consumption differs between the borrowing and no-borrowing cases.

Farmer utility from borrowing is found by looping over months, adding the utility from each month. In our empirical context, borrowers were given three months between being notified of the loan opportunity and paying the deposit. Thus in calculating utility from borrowing, it is assumed that the deposit is saved up for over three months. Thus utility from the first three months is given by

$$\sum_{i=0}^{2} \delta^i u(10,000 - x(6,000,2)). \tag{42}$$

At the beginning of the fourth month, the borrower receives the tank, which provides total lifetime utility y, and begins paying off the loan, thus gaining discounted utility

$$\delta^3 (y + u(10,000 - 1,000 - interest)), \tag{43}$$

where the variable *interest* is as defined above. Utility over the remaining months is given by

$$\sum_{i=4}^{20} \delta^i u(10,000 - 1,000 - interest). \tag{44}$$

Thus total borrowing utility is given by

$$u_{borrow} = \sum_{i=0}^{2} \delta^i u(10,000 - x(6,000,2)) + \delta^3 (y + u(10,000 - 1,000 - interest)) + \sum_{i=4}^{20} \delta^i u(10,000 - 1,000 - interest). \tag{45}$$

Tank value v_{tank} is given by solving for the y such that $v_{borrow} = v_{noborrow}$.

Utility Given a Saving Window

The "Utiltiy Given a Saving Window" function receives calibration parameters, a savings window (number of months spent saving up for the deposit), a deposit requirement, and the value p which is used as described above to calculate the welfare value of a lower deposit, and returns a farmer's utility over a given span of months n. The function requires a fixed number n of months which is large enough to exceed the time needed to pay off the loan for any reasonable savings window. n is held fixed so as to allow direct comparisons of utility across saving windows when calculating optimal saving times. The utility calculation performed by this function can be split into five periods: the first month pre-loan (month 1), the remaining pre-loan months (months 2 through $i_{deposit}$, the end of the saving window), repayment month one (month $i_{deposit} + 1$) in which the borrower receives the tank, the remaining repayment months ($i_{deposit} + 2$ through $i_{deposit} + 18$ if the deposit requirement is 6,000 KSh, and $i_{deposit} + 2$ through $i_{deposit} + 23$ if the deposit requirement is 1,000 KSh), and post-repayment. The post-repayment period runs from the end of the repayment months through to month n. To calculate overall utility, we run a loop summing (discounted) utility across months, with each month's utility determined by the period in which it lies. In the first month, the borrower's utility is

$$u(10,000 + p - x(Deposit, i_{deposit})), \tag{46}$$

In the remaining pre-loan months, borrower utility is

$$\delta^{month-1} u(10,000 - x(Deposit, i_{deposit})). \tag{47}$$

In the month after receiving the loan, utility is

$$\delta^{month-1} [v_{tank} + u(10,000 - (1,000 + interest))]. \tag{48}$$

Utility in the rest of the repayment months is

$$\delta^{month-1} u(10,000 - (1,000 + interest)). \tag{49}$$

Utility in the post-repayment months is

$$\delta^{month-1} u(10,000). \tag{50}$$

Utility with Saving Optimization

The "Utility with Optimization" function receives the utility parameters, a deposit requirement, and p. Looping over all possible savings windows from 1 to n - 23 (this is the largest savings window over which all months in which borrowing affects consumption are contained in the size-n time frame used by the "Utility Given a Savings Window" function), this function runs a basic grid search algorithm over values of "Utility Given a Saving Window" with all inputs other than the savings window matching those received by "Utility with Saving Optimization." The grid search calculates the savings window that maximizes utility for the given inputs, and

Calibration Results Under Alternative Parameters

	$\theta = 1.005$	$\theta = 2$	$\theta = 0.5$	$\theta = 3$
v_{tank}	.9783 1260	.9718 1278	.9825 1240	.9639 1286
$2v_{tank}$	.9960 1782	.9927 2143	.9972 1573	.9894 2567
$5v_{tank}$	.9988 2005	.9976 2506	.9992 1641	.9965 2850
$10v_{tank}$	.9994 2005	.9989 2506	.9996 1641	.9983 2850

Table shows calibration results under alternative parameter assumptions.
Rows denote multiples of minimum tank value v_{tank}, described in more detail above.
Top value in each cell is maximum yearly discount factor such that borrower gains outweigh SACCO losses.
Bottom value is equivalent variation welfare gain from lowering deposit requirement.
Due to computation time constraints, this table is based on borrowers who can save up for the tank for at most 100 months.
This constraint only binds at extremely low discount rates. Because the constraint limits the tank-consumption-timing benefits of a lower deposit when it binds, the resulting δ estimates are likely lower than unconstrained estimates would be.

returns the size of that window and the value of "utility with Saving Optimization" given that window.

Alternative Calibration Parameters

The calibration results are robust to alternative assumptions on key parameters, as recorded in the below table. Results in each row share the same borrower tank valuation. For example, in the second row, borrowers are assumed to gain twice as much utility as v_{tank}, the tank utility required to make borrowers indifferent to borrowing at the 25% deposit level. Results in each column share the same coefficient of relative risk aversion θ. The top value in each cell is the maximum yearly discount factor such that the benefit to borrowers of lowering the deposit from 6000 KSh to 1000 KSh exceed the total costs to the SACCO. The bottom value is the welfare gain per inframarginal borrower from lowering the deposit. Benefits outweigh costs so long as this value is greater than $\frac{73}{.57} = 128$.

Tables

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

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