Joint Liability, Asset Collateralization, and Credit Access: Evidence from Rainwater Harvesting Tanks in Kenya *

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June 15, 2015

Abstract

Do stringent formal sector borrowing requirements in developing countries restrict credit access? Randomization of borrowing requirements for Kenyan dairy farmers purchasing rainwater harvesting tanks yields no evidence that substituting joint liability requirements for deposit requirements increased credit access. In contrast, allowing borrowers to collateralize loans primarily with the asset purchased under the loan increased borrowing dramatically, from 2.4% to 44.3%. All 460 loans were fully recovered, in one case out of the proceeds from a repossession. Results were similar in a second, out-of-sample, set of loans . A Karlan-Zinman test based on waiving borrowing requirements ex post yields no evidence that borrowing requirements have a negative treatment effect on tank repossession, but suggests they select safer borrowers (significant at the 5.25% level). A simple model suggests that such selection effects will cause profit-maximizing lenders to set borrowing requirements above the socially optimal level, because lenders will not internalize costs to infra-marginal borrowers. and cCalibrations suggest that tight borrowing requirements may be privately, but not socially optimal. Allowing borrowers to collateralize loans with purchased assets had real effects on water access, time use, and girls' school enrollment. Although nearly 95% of borrowers were subject to credit constraints, many repaid loans early. While a decisive test awaits further work, the model suggests prospect theory could potentially account for both the sensitivity of loan take up to the ability to allowing collateralize collateralization of loans with purchased assets, high repayment rates, and for widespread early repayment.

*The authors would like to thank Egor Abramov, William Glennerster, Benjamin Marx, Adam Ray, Itzchak Raz, Indrani Saran, and Kevin Xie, for exceptional research assistance. Our gratitude also goes out to Suleiman Asman, Antony Wainaina and Nadir Shams for excellent management, field supervision and data collection. We are grateful to Joshua Angrist, Michael Boozer, Esther Duflo and Rachel Glennerster and seminar audiences at the Northwestern, Georgetown, the IPA Microfinance Conference, UCSD, Tinbergen Institute, Amsterdam, the World Bank and MIT Development Lunch for comments. We thank the Gates Foundation, Google and the Agricultural Technology Adoption Initiative for funding.

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1 Introduction

Formal credit markets are typically much less developed in low-income than high-income countries (Rajan and Zingales, 1998; La Porta et al., 1997, World Bank, 2014). Lenders typically set strict borrowing requirements, for example with high down payment requirements for mortgages. Joint liability loans, such as those offered by many microfinance borrower groups or by banks who require co-signers for loans, are often seen-as a key instrument for expanding credit access in low income countries (Morduch, 1999; Hermes and Lensink, 2007). However, uptake is often limited (Banerjee et al., 2015).

In this paper, we examine the extent to which tight borrowing requirements constrain borrowing and the extent to which joint liability requirements can expand credit access, using take advantage of an experiment in which a Kenyan savings cooperative randomly varied collateral and joint liability requirements for dairy farmers to borrow to purchase rainwater harvesting tanks to examine the extent to which tight borrowing requirements constrain borrowing and the extent to which joint liability requirements can expand credit access. The design incorporated ex post waivers of deposit and guarantor requirements (as in Karlan and Zinman, 2009) to allow measurement of how deposit and guarantor requirements affect both selection of borrowers and repayment incentives. Following the initial set of loans, the cooperative made another set of loans to provide an out-of-sample test.

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. We also do not find substantial differences in repayment between individual and joint liability. [1]

On the other hand, allowing borrowers to collateralize loans using assets purchased with the loans dramatically increases borrowing. Only 2.4% of farmers borrowed under the savings cooperative's standard borrowing conditions, which require that one third of the loan be secured with deposits by the borrower, and that the remaining two thirds be secured with cash or shares from guarantors. The loan take up rate increased more than ten-fold, to 27.6%, when only a 25% deposit was required and the rest of the loan could be collateralized with the tank itself. Loan take up increased to 44.3% when all but 4% of the loan could be collateralized with the purchased tank.

All 460 loans were fully recovered by the lender. There was one tank repossession in the 4%

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

deposit group, but the proceeds from the sale of the tank were sufficient to fully repay the loan. Results were similar in a subsequent out-of-sample test. The combined sample had full loan recovery and less than one percent tank repossession in the 4% deposit arm, and no tank repossessions with 25% deposit or guarantor requirements. We find no evidence that moving from full cash collateralization to a 25% deposit requirement increases tank repossession. After seeing the results of the program, the lender changed its policy to allow 75% collateralization with the tank. We On the other hand, we estimate that moving from a 25% to a 4% deposit requirement induces one marginal tank repossession for every 62 additional borrowers, and we can reject the hypothesis of equal rates of tank repossession rates under a 4% deposit requirement and under a 25% deposit or guarantor requirement at the 5.25% level. This difference is entirely due to selection, rather than treatment effects. Stricter borrowing requirements reduced the number of borrowers who ever made late payments, and there is evidence (significant at the 7% level), that this is due to selection effects.

A simple model suggests that if borrowing requirements impose costs on borrowers, but select more profitable borrowers, lenders will set tighter borrowing requirements than would a social planner. To see the intuition, note that the first order condition for a profit maximizing lender setting deposit levels will be based on the characteristics of the marginal lenders selected by marginally tightening borrowing requirements, but tightening borrowing requirements also imposes costs on inframarginal lenders that will be taken into account by a social planner but not a profit maximizing lender. Rough calibrations based on the lenders' interest rates, late fees, repossession charges and administrative costs, as well as the estimated response of borrowers to easier credit terms and estimated selection effects, suggest that for plausible parameter values, allowing borrowers to collateralize 96% of their loans with the purchased asset and requiring only 4% collateralization with pre-existing assets might well have been welfare maximizing, but was not profit maximizing, among the alternatives we examined. (Indeed, 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.

Easing access to credit had real effects. Farmers offered the opportunity to collateralize loans with the tanks had more water storage capacity and were more likely to own large rainwater harvesting tanks. These results, along with those of Devoto et al. (2013), suggest that improving credit access can contribute to increasing access to clean water in the developing world. They also provide support for the idea that credit access may influence technology adoption (Zeller et al., 1998). Children of households offered less restrictive credit terms spent somewhat less time collecting water and tending livestock and difference-in-difference estimates suggest fewer girls in these households were out of school. Our data is far too noisy to rule out either no production impact or a large impact (this result is similar to that in the randomized control trials on microfinance summarized by Banerjee et al., 2015). There is evidence of an increase in milk sales during the period before loan maturation, particularly outside the top of the distribution, consistent with the hypothesis that farmers sold more milk to the dairy to pay off their loans.

While Oour data suggest that at least 40 percent of farmers wish to buy tanks but are credit constrained,. Ssome features of the data, however, are surprising from the standpoint of the simplest credit constraint stories, and suggest that other factors may also be at play. First, one might expect that some credit constrained farmers would have friends or relatives who were not credit constrained and who would be willing to serve as guarantors, yet substituting joint liability requirements for deposit requirements had no effect on loan take up. Second, under a standard credit constraint story, one might expect that the tight borrowing requirements in the standard savings cooperative contract would select richer borrowers. However, borrowers in this arm do not have greater wealth than those in other arms (although estimates are noisy). Finally, many farmers repaid the loans early, effectively foregoing an approximately zero-interest loan. For example, borrowers in the fully cash collateralized arm repaid loans an average of 15 months earlier than the stipulated 24 month period. When borrowers' deposits were waived, leaving them free to withdraw the funds, many instead applied the deposits to repay the loan for the rainwater harvesting tank early.

The model suggests that prospect theoretic preferences (Kahneman and Tversky, 1979) could potentially provide a unified explanation of low loan take up when loans have to be collateralized with existing assets, high loan take up when loans can be collateralized with assets purchased under the loan, and high repayment and early payment rates. Under prospect theory, people value gains and losses relative to a reference point, with greater disutility from losses relative to this reference point than utility from gains. Assuming the reference point is set based on the status quo, prior to obtaining a tank as in Kahneman and Tversky (1979), prospect-theoretic agents would be reluctant to risk obtain a tank if this required risking existing assets or relationships by collateralizing loans with those pre-existing assets or finding guarantors in order to obtain a tank. They would be more willing to risk losing the tank, an asset that they do not yet own. After buying the tank, however, their reference point shifts and they will sacrifice in other areas to avoid losing the tank. While our data are consistent with prospect theory, other explanations are also possible, and a decisive test would require future research.

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 simple model with which we interpret the data. Section four explains the experimental design and section five explains the data and our empirical specifications. Section six discusses the impact of borrowing requirements on loan take up and on borrower characteristics. Section seven discusses the treatment, selection, and overall impacts of relaxing borrowing conditions on loan recovery, tank repossession, and late payment, and calibrates the model to the data. Section seven also includes a calibration of the model. Section eight discusses early payment, and the potential role of prospect theory in accounting for results on borrower behavior. Section nine discusses the impacts on real outcomes. Section ten concludes.

2 Background

Approximately 900 million people lack access to water at their homes (WHO and UNICEF 2010). Collection of water from distant, potentially contaminated, sources reduces water use for hand washing and cleaning, with potential negative health consequences (Wang and Hunter, 2010; Esrey 1996), and imposes a substantial time burden, particularly for women and girls with potentially negative consequences for schooling. [2] and reduces availability of water for hand washing and cleaning, with potential negative health consequences (Wang and Hunter, 2010; Esrey 1996). Devoto, (2013) finds that provision of household water connections leads to lower levels of intra- and inter- family conflict and higher wellbeing, even in the absence of health and income gains.

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]

We examine a population of dairy farmers in a relatively high rainfall area straddling Kenya's Central and Rift Valley provinces. Dairy farmers have greater incentives than other households of comparable income to invest in rainwater harvesting systems because dairy cattle require a regular water supply (Nicholson (1987), Peden et al. (2007), and Staal et al (2001)) and in the area we study rainwater harvesting systems can meet a substantial portion of water needs for small holder dairy farmers. Without easy access to water, the most common means of watering cattle is to take them to a source every two or three days, which is time consuming and can expose cattle to disease (Kristjanson et al. 1999). [4]

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.

[2]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.

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

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

Historically, many farmers in the area used stone or metal tanks to harvest rainwater and store water for days when piped water is not available. 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, introduced about 10 years ago, now dominate the market. Rainwater harvesting tanks provide extremely 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. Installation requires installing gutters attached to the corrugated iron roofs that are ubiquitous in this area. Tanks are also typically put on a raised platform. Approximately one-quarter of comparison group farmers had a water storage tank of more than 2,500 liter capacity at baseline.

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 with which we worked performs basic quality tests, cools the milk, and then sells it to a large-scale milk producer for pasteurization and sale to the national market. It keeps track of milk deliveries and pays farmers monthly. During the time period we study, selling to the Nyala dairy was more lucrative for farmers than selling on the local market or to another dairy, which would have involved higher transport costs.[5]

Like many dairy cooperatives, the Nyala cooperative has an associated savings and credit association or SACCO.[6] The 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 2008 the SACCO made 292 cash loans to members, averaging KSh 25,000 ($315). [7]

The institutional context is 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. Third, a savings and credit cooperative associated with a farmer-owned dairy

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

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

[7]As of December 2010, there were 6,007 registered SACCOs in Kenya. With total membership at 1.8 million or 4.8 percent of the national population, SACCOs play an important role in the Kenyan financial sector.

cooperative may have more legitimacy in collecting debt than would an outside lender.

The SACCO has strict borrowing requirements typical in the sector. In particular, it requires full collateralization of loans. 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 their savings shares and/or savingsshares in the cooperative. In this paper we report on the results of a program in which the SACCO made loans for farmers to purchase rainwater harvesting tanks, allowing farmers to use the tanks themselves as collateral. Rainwater harvesting tanks are well-suited as collateral - they are big and have to be installed next to the user's house, so they are easy to find. 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. They have no moving parts and are durable and standardized, so they preserve much of their value, allowing a lender repossessing tanks to sell them.

3 Model[8]

In order to help to motivate the empirical work in subsequent sections we present a simple model following Stiglitz and Weiss (1981) in which strict borrowing requirements can potentially both incentivize borrowers and select more profitable borrowers. We show that if strict deposit requirements select more profitable marginal borrowers and impose costs on inframarginal borrowers, lenders will generically choose stricter deposit requirements than socially optimal.

In the rest of this section, we set up the model, solve for the optimal loan take up and repayment behavior by farmers given the lender's choice of deposit requirements, and then solve for the lender's profit-maximizing choice of borrowing requirement given farmer behavior. We then show that these requirements will generically be too stringent from a social point of view if stricter borrowing requirements select more profitable borrowers.

3.1 Assumptions

We consider an economy with one monopoly lender, which can borrow at an international interest rate R_L and lend to farmers, and with a continuum of farmers. Farmer i's valuation of the tank is denoted θ_i. Water tank valuation is continuously distributed over the interval $[\underline{\theta}, \bar{\theta}]$

[8]We thank Egor Abramov, William Glennerster, and Itzchak Raz for his help on this section.

according to some (non-degenerate) cumulative distribution function $F(\theta)$. We assume that the distribution has positive density throughout its support and has no mass points. θ_i encompasses utility benefits of the tank, time savings, and any dairy farming productivity benefits. Variation in the value of tanks might arise from factors like distance from other water supplies, labor availability in the household, and taste for clean water. Farmers value consumption of a composite good as well as water tanks.

Farmers have an initial wealth w at period $t = 1$ and future stochastic income y_i at period $t = 2$. For simplicity, assume that y_i can be either y_L with probability $\pi_L \in (0, 1)$ or y_H with probability $1 - \pi_L$. Farmers can purchase tanks in period $t = 1$ through a contract with the lender.

We assume that the farmers are credit constrained, i.e., that they have access to investment opportunities that generate returns R_B which are greater than the international interest rate R_L at which the lender can borrow, but that they lack the funds to take all of these opportunities.[9] Farmers thus have non-tank investment opportunities at period $t = 1$. $R_B > 1$ is the gross return on the marginal non-tank investment which matures at period $t = 3$. The lender pays borrowers interest on deposits R_D where $R_L < R_D < R_B$.[10] The tank value in shillings is C and it has to be repaid to the lender along with interest payments Q. We assume that there is a limited liability constraint so that if the borrower fails to repay, the only assets which can be seized are the pledged deposit and the tank. If the lender repossesses the tank it can resell it for δC. [11] A repossession event incurs an expected total cost $K \geq 0$ (e.g., rental costs for a truck to move the tank, management time, the risk of tank negative publicity or vandalism by a disgruntled borrower or negative publicity). If the tank is repossessed, it is sold, and the lender is repaid the principal, interest, and late fees, as well as a repossession fee, with any tank proceeds remaining after these deductions going to the borrower. We assume that there is some maximum repossession fee, denoted K_{maxB}, that the borrower can be charged and that this is less than K. For example, in the program we examine the contract allowed the lender to deduct administrative costs of repossession, but the amount the lender charged was

[9] We also consider two amendments to the model. First, we let the borrowers be credit unconstrained - that is they either have no access to outside investment opportunities or have sufficient funds to both pay the deposit and implement outside projects. Second, we model credit constraints in a different manner: borrowers have no outside investment opportunities and might not have enough funds to pay the deposit. We derive the implications of these extensions at the end of the theory section and show that these implications do not get along with the pattern observed in the data.

[10] In the study the lender paid an interest rate R_D of 3% a quarter on cash deposits. This is very close to the rate of interest the lender charged borrowers. Hence, $R_D = \frac{C+Q}{C}$. This assumption allows for $R_D = \frac{C+Q}{C}$ but also allows for the more general case where $R_L \leq R_D < R_B$

[11] A natural assumption is that δ is less than 1 and $(1 - \delta)$ is the depreciation rate. In the actual program however, tanks were purchased at the wholesale price, so it is possible that a repossessed tank might be sold for more than the purchase price. Indeed, in one of the tank repossessions in the study the sale price of the tank exceeded the value of the loan principal.

approximately half the cost of truck rental, security for repossession, and management time. This does not include the risk of an irate borrower vandalizing a tank or the dairy itself, or the costs of negative publicity.

The lender is risk neutral and chooses a required deposit value D^* to maximize expected profits. [12]The rest of the loan value is collateralized with the tank itself. The case of full asset collateralization thus corresponds to $D = C$, while an uncollateralized loan has $D = 0$. Note that setting $D > 0$ reduces farmers' available funds for alternative investment.

We will let $\pi(\theta, D)$ denote the proportion of borrowers with valuation θ who will allow their tank to be repossessed when the deposit is set by the lender at D.

There are three periods:

1. At period $t = 1$ the lender and the farmers (borrowers) meet, the lender chooses the required deposit D, and farmers decide whether or not to take the loan. We allow both for reference independent preferences and for the case in which farmers have reference dependent preferences and put a weight $\lambda > 1$ on losses relative to a reference point. (We will follow Kahnemann and Tversky (1979) in modeling the reference point as dependent on the status quo, rather than as forward looking.) If farmers have reference dependent preferences, they attach weight $\lambda > 1$ to the prospect of paying a deposit. If not, then $\lambda = 1$

2. At period $t = 2$ farmer income y_i is realized and the loan is to be repaid. We will assume that $Y_H > C + Q$, so that farmers with favorable income realizations have sufficient funds to pay back the principal and interest even if $D = 0$. We will also assume that $Y_L < Q$ so that farmers with unfavorable realizations do not have sufficient funds in order to repay even if $D = C$. Farmers with bad realizations can either allow the tank to be repossessed, thus losing the tank but getting the remainder of the proceedings from a tank sale minus after the deductions for the amount owned to the lender and the repossession costs, K_{maxB}, or can liquidate a portion of their other investments at the cost of losing the net returns $R_B - 1$ and $R_D 1$ on the liquidated investments and deposit, respectively. If farmers liquidate their investments in order to repay the loan we assume that first they use their deposit to repay the loan (at the cost of losing its net accrued interest $R_D - 1$) and then, if required, liquidate their non-tank investments. If farmers have borrowed and purchased the tank, then their reference point in period two includes the tank.

3. To keep notation simple, we will assume that utility from consumption of the tank and of other goods is realized at in period 3.

[12]We focus on the case in which the lender offers only a single contract, rather than a menu of contracts . However, the results of the section can be extended to the case of menu of contracts - see footnote 20.

Below we will prove that in this economy, given some regularity conditions specified below, and outside of one special case, the lender chooses deposit requirements that are too high from a social point of view, in the sense that decreasing D from the profit maximizing level, D^*, will cause a second order loss to the lender and but a first-order gain for borrowers.

To show this, we first solve the farmer's problem of whether to borrow and whether to repay given the D chosen by the lender. We then solve for the first-order conditions for the profit-maximizing D^* for the lender, and show how this differs from the social optimum.

3.2 The Farmers' Problem

Farmers face the decisions given the deposit requirement of whether to take out a loan, and whether to repay the loan if necessary by liquidating a portion of their other assets and giving up the return on those assets. We solve backwards, working from the decision of whether to repay the loan or allow tank repossession. Define the utility of individual i in period 3 as $U_{repay}(y_i, D; \theta_i)$, if the tank is not repossessed, and $U_{default}(y_i, D; \theta_i)$, otherwise.

Conditional on having taken up the loan, if a farmer gets a high income, she can repay the loan without liquidation of other assets, and her period three utility is

$$U_{repay}(Y_H, D; \theta_i) = \theta_i + Y_H - (C + Q) + R_B(w - D) + R_D D. \tag{1}$$

The farmer obtains the benefit of the tank, θ_i, their period two income net of the principal and interest payments due, $Y_H - (C + Q)$, the gross return on non-tank investment, $R_B(w - D)$, and the gross return on their deposit, $R_D D$. If the farmer gets a low income, she has to liquidate a portion of her non-tank investments in order to repay the lender, the utility is

$$U_{repay}(Y_L, D; \theta_i) = \theta_i + R_B(w - C - Q + Y_L), \tag{2}$$

i.e., the benefit of the tank , $\theta_i - (C + Q)$, plus the gross return on non-liquidated non-tank investments. The farmer owes the principal and interest payments, $(C + Q)$, which he must pay off using his income, Y_L, the deposit D, and liquidating $C + Q - Y_L - D$ of initial wealth, and thus will earn a return on the remaining non-liquidated assets of $R_B(w - C - Q + y_i))$.

To derive for utility of a farmer who does not repay the loan and allows the tank to be repossessed, we first derive the payment the farmer receives from the sale of the tank.

In the event of a repossession, a borrower will receive their net equity in the tank if it is positive and get no money back if their net equity is negative. The net equity of the borrower is equal to the total value of the tank and the deposit, $D + \delta C$, minus the total claims of the lender in the event of repossession, $C + Q + K_{maxB}$. Hence, the borrower will receive $\max\{D - (1 - \delta)C - Q - K_{maxB}, 0\}$ in the event of a repossession and the total borrower utility in the event of repossession is

$$U_{default}(y_i, D; \theta_i) = -(\lambda - 1)\theta_i + y_i + (w - D)R_B + \max\{D - (1 - \delta)C - Q - K_{maxB}, 0\}. \quad (3)$$

The first term, $-(\lambda - 1)\theta_i$, represents the disutility borrowers with reference dependent preferences who do not repay and allow their tank to be repossessed will incur from losing the tank. The other terms represent the utility borrowers obtain from their period two endowment y_i, the gross return on non-tank investment $(w - D)R_B$, and any proceeds from the sale of the tank.

Repossessions only occur when $y_i = y_L$ is realized, since high-income farmers will not need to liquidate investments to repay the tank loan and will not want to incur the cost of losing the return on their investments.

Comparing the utilities from liquidation and repossession yields the condition for repossession, conditional on borrowing at $t = 1$. A farmer will only fail to repay the loan and allow the tank to be repossessed if she earns low income and the utility from repossession exceeds the utility from liquidation of investments[13]:

$$U_{default}(Y_L, D; \theta_i) \geq U_{repay}(Y_L, D; \theta_i), \quad (4)$$

We assume that the distribution of water tank valuation has positive density throughout its support and that the lower support of the distribution includes farmers whose valuation of a tank is less than C and the upper support is high enough that they would be willing to purchase a tank even if $D = C$ so they had to fully collateralize the loan. Under these conditions a marginal farmer exists, denoted by $\underline{\theta} < \theta^R(D; \lambda) < \bar{\theta}$, who is indifferent between liquidating and allowing the tank to be repossessed.

$\theta^R(D; \lambda)$ defines a repossession probability function, conditional on borrowing, denoted by $\pi(\theta_i, D)$. For farmer i with $\theta_i \geq \theta^R(D; \lambda)$ the repossession probability is zero and for farmer i with $\theta_i < \theta^R(D; \lambda)$ the repossession probability is π_L, conditional on taking the loan. Note that $\pi(\theta_i, D)$ is decreasing in both of it's arguments. The higher the value of the tank for the farmer,

[13] Notice that repossession can occur only under low income because borrowers rationally take the loan only if they want to keep the tank at least in the good state of the world

the less likely she is to allow it to be repossessed. Similarly, the higher the deposit, the less likely that a farmer will allow the tank to be repossessed and the deposit to be lost. The first argument θ_i is the selection effect of a higher deposit while the second is the treatment effect. Finally, note that $\theta^R(D;\lambda)$ is decreasing in λ, i.e. the more borrowers are averse to losses relative to the status quo, the less likely they are to allow the tank to be repossessed.[14]

Having solved for repayment behavior conditional on borrowing we can now solve for borrowing behavior. At period $t = 1$ farmer i will borrow if their utility from not borrowing is lower than their expected utility from borrowing. The utility a farmer receives if they do not borrow is equal to their period two income y_i plus their gross return on investing all of their period one wealth in non-tank investments, $R_B w$. The utility of a farmer who borrows is the weighted average of their utilities when they receive low and high income. Specifically, a borrower's expected utility will be equal to the utility they receive with a low income multiplied by π_L plus the borrower's utility with a high income multiplied by $(1 - \pi_L)$. When income is high, utility is equal to the value of the tank net of the interest and principal payments plus period two income, the gross return on non-tank investments, and the deposit and its accrued interest. When income is low, the utility derived depends on whether the borrower decides to allow their tank to be repossessed.

A borrower will allow their tank to be repossessed if they earn a low income and $\theta_i \leq \theta^R(D;\lambda)$. In this case the borrowers expected utility from borrowing will be equal to the weighted average of their low income utility of default, $U_{default}(Y_L, D; \theta_i)$ and their high income utility of keeping the tank, $U_{repay}(Y_H, D; \theta_i)$. As a farmer will borrow if their expected utility from borrowing exceeds their expected utility from not borrowing, equal to $\bar{U} = \mathbb{E}y_i + R_B w$. If $\theta_i > \theta^R(D;\lambda)$, the borrower will choose to liquidate non-tank investments instead of allowing their tank to be repossessed. Hence, a farmer will borrow if

$$\pi_L \max\left\{U_{default}(Y_L, D; \theta_i), U_{repay}(Y_L, D; \theta_i)\right\} + (1 - \pi_L)U_{repay}(Y_H, D; \theta_i) \geq \bar{U}. \tag{5}$$

As before we are assuming that the support of the cumulative distribution function $F(\theta_i)$ is such that a marginal farmer exists, denoted by $\theta^*(D;\lambda) < \bar{\theta}$, who is indifferent whether to borrow.[15] Higher valued farmers will borrow while lower types will not. Thus, the mass of farmers who borrow is given by $1 - F(\theta^*(D;\lambda))$. Note that $\theta^*(D;\lambda)$ is also increasing in λ, i.e. greater loss aversion reduces the number of farmers who borrow.

[14]Recall that reference points are based on the status quo, so while the principal of alternative investments enters into farmers reference point, the return on this investment does not.

[15]Note that for the non-degenerate case in which $\bar{\theta} > C + Q$ for every D there exists $\pi_L > 0$ which is sufficiently low to insure that $\theta^*(D;\lambda) < \bar{\theta}$.

Consider the total farmer utility:

$$\mathbb{U}_{total}(D;\lambda) = \theta^*(D;\lambda)\bar{U} + \int_{\theta^*(D;\lambda)}^{\theta^R(D;\lambda)} \left[\pi_L U_{default}(Y_L, D; s) + (1-\pi_L)U_{repay}(Y_H, D; s)\right] \mathrm{d}F(s) + \int_{\theta^R(D;\lambda)}^{\bar{\theta}} \left[\pi_L U_{repay}(Y_L, D; s) + (1-\pi_L)U_{repay}(Y_H, D; s)\right] \mathrm{d}F(s). \quad (6)$$

An increase in D would cause total farmer utility to fall, since . To see this, notice that the expected utilities for each group of farmers declines: $\frac{\partial}{\partial D}U_{repay}(Y_H, D; s) = -(R_B - R_D) < 0$, $\frac{\partial}{\partial D}U_{default}(Y_L, D; s) = -(R_B - \mathbb{I}_e) < 0$[16], and $\frac{\partial}{\partial D}U_{repay}(Y_L, D; s) = 0$. Hence[17],

$$\frac{\partial}{\partial D}\mathbb{U}_{total}(D;\lambda) = \int_{\theta^*(D;\lambda)}^{\theta^R(D;\lambda)} \left[\pi_L \frac{\partial}{\partial D}U_{default}(Y_L, D; s) + (1-\pi_L)\frac{\partial}{\partial D}U_{repay}(Y_H, D; s)\right] \mathrm{d}F(s) + \int_{\theta^R(D;\lambda)}^{\bar{\theta}} \left[(1-\pi_L)\frac{\partial}{\partial D}U_{repay}(Y_H, D; s)\right] \mathrm{d}F(s) < 0. \quad (7)$$

Intuitively, this is because a higher D ties up more of the farmers wealth earning at most R_D,[18] and this lowers the amount borrowers can invest in higher returning non-deposit investments, which earn $R_B > R_D$. Further, a rise in D increases the amount of money the bank can reclaim from the borrower in the event of a default. This can be seen by considering the utility of three groups of farmers: inframarginal farmers who would have borrowed at a low D and continue to borrow as a result of the increase in D; marginal farmers who would have borrowed but no longer borrow; and farmers that would not have borrowed at the original D and will continue to not borrow.

Inframarginal farmers who continue to borrow after a change in D lose out on the interest they could have earned through investing the capital in non-tank investments. They experience an expected loss that is of the first order in ΔD. Farmers who earn y_H and repay their loan using their period two income lose $\Delta D(R_B - R_D)$ in the case of high income. Borrowers who allow their tank to be repossessed also lose out, i.e. they lose $\Delta D(R_B - \mathbb{I}_e)$. Farmers who continue to borrow after an increase in D but liquidate their assets are no worse off in this model as they use

[16] $\mathbb{I}_e$ is the indicator of positive borrower's equity and equal to one if and only if $D - (1-\delta)C - Q - C_{maxB} > 0$.

[17] Notice that the derivative of $\mathbb{U}_{total}(D;\lambda)$ with respect to D does not include terms containing $\frac{\partial}{\partial D}\theta^*(D;\lambda)$ and $\frac{\partial}{\partial D}\theta^R(D;\lambda)$. This is an outcome of the envelope theorem: both $\theta^*(D;\lambda)$ and $\theta^R(D;\lambda)$ are the outcomes of maximization problem. For instance, the term containing $\frac{\partial}{\partial D}\theta^*(D;\lambda)$ is equal to $\frac{\partial}{\partial D}\theta^*\left(\bar{U} - \left[\pi_L \frac{\partial}{\partial D}U_{default}(Y_L, D; \theta^*) + (1-\pi_L)\frac{\partial}{\partial D}U_{repay}(Y_H, D; \theta^*)\right]\right) = 0$.

[18] If the deposit is used at period $t = 2$ in order to pay back the loan the net return on the deposit is zero.

all the deposit to repay the loan. Hence, all farmers who continue to borrow after an increase in D are strictly worse off in the expectation.

Farmers who would not borrow originally will continue to not take up the loan as the higher capital requirement makes it less attractive to borrow. Thus, farmers who would originally not borrow continue to not borrow and hence their utility is unchanged by varying the capital requirement of borrowing.

Marginal farmers who would have borrowed at a low level of D but will not after an increase in D will be worse off. Originally these farmers when choosing whether to borrow or not selected to borrow showing that borrowing gave farmers higher utility. When D is increased this makes borrowing less attractive but the utility from not borrowing is unchanged. Thus the farmers who switch to not borrowing as a result of an increase in D are less well off than at the low level of D, but they experience a second-order loss.

In sum, inframarginal farmers experience a first order loss from an increase in D and other farmers either experience a second-order loss or experience no change in utility. Overall, farmers strongly prefer lower level of deposit for any given comparison.

3.3 The Lender's Problem

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

$$P_{loan}(D) = Q + C - (R_L(C - D) + R_D D) + \pi_L(R_D - 1)D \tag{8}$$

per customer when there is no repossession, equal to the interest paid by the borrower minus the cost of borrowing the capital to finance the loan. The capital the lender raises to make the loan comes from the deposit and its borrowing from the world market. Hence, the cost to the lender of raising the capital is $R_L(C - D) + R_D D$ unless a borrower liquidates the deposit to repay the loan - in the latter case, the cost is $R_L(C - D) + D$.

If a repossession occurs, then the lender's utility depends on D and whether the borrower has positive or negative equity; while the lender can always seize the deposit and tank, the farmer only winds up covering interest and repossession fees if they have sufficient equity in the tank. If the borrower does not have sufficient equity in the tank, the lender will not be able to fully recover interest and repossession fees. If a repossession occurs the lender will immediately seize the deposit, D, and sell the tank for δC. The lender will incur the cost of repossession, K in addition to the previous outlay on borrowing the capital for the loan, $R_L(C - D) + D$. If the borrower has positive equity in the tank the lender will also have to pay the proceeds of the tank sale net of interest and repossession fees, $max\{D - (1 - \delta)C - Q - K_{maxB}, 0\}$ to the borrower.

Hence, the net value of a loan to the lender in the event of repossession is $D+\delta C-K-(R_L(C-D)+R_D D)-\max\{D-(1-\delta)C-Q-K_{maxB},0\}$. Comparing the profits with and without repossession, we obtain the expression for the loss per default for the lender:

$$L_{default}(D)=K-D+\max\{D-K_{maxB},Q+(1-\delta)C,0\} \tag{9}$$

Let $\mathbf{\Pi}(D)$ denote the net profit of the lender, which the lender maximizes over D, subject to the constraint that returns on lending for tank purchase is at least as high as the lender's alternative return $R_L<\frac{C+Q}{C}$. A marginal change in the required deposit will have an effect both on the intensive margin of reducing repossession risk for existing borrowers and on the extensive margin of reducing the number of borrowers and changing their type. On the intensive margin, a rise in D will reduce tank repossessions risk since borrowers will be less willing to allow the tank to be repossessed thereby losing the deposit. This is the treatment effect of D. On the extensive margin, it will reduce both the total number of loans and thus the total profit from loans with no repossession and the expected loss from repossessions. This is the selection effect. The deposit D also has two non-marginal effects: first, a low D implies higher costs for the lender in a case of repossession but lower[19] costs of funds in a case of no default. The former effect provides further incentive to the lender to require a high deposit. Finally, even though the latter effect disincentives the lender from raising D, we argue that this effect is negligible, for $R_L\approx R_D$ in the data. The lender's problem is given by

$$\max_D \mathbf{\Pi}(D) = \max_D\{(1-F(\theta^*(D)))P_{loan}(D)-\left(F(\theta^R(D))-F(\theta^*(D))\right)\pi_L L_{default}(D), \tag{10}$$

where P_{loan} is the lenders profit per repaid loan and $(1-F(\theta^*(D)))$ is the number of successful loans given out. Hence, the term $P_{loan}(1-F(\theta^*(D)))$ is the lenders profit if all loans are repaid and no loans resulted in default. $L_{default}$ is the net loss per default that measures the difference in profitability of a repaid loan compared to a defaulted loan. $\left(F(\theta^R(D))-F(\theta^*(D))\right)\pi_L$ is the number of loans that default for a given level of D: the total number of people who take the loan and default in case of low income is $F(\theta^R(D))-F(\theta^*(D))$, and it is multiplied by the individual probability of low income, π_L.

D^* is characterized by the lender's first order condition, which will require equalizing the

[19] This is due to the fact that $R_D\geq R_L$.

marginal cost and benefits of raising the required deposit. We obtain the following FOC:

$$(1-F(\theta^*))P'_{loan}(D)-\frac{\partial\theta^*}{\partial D}f(\theta^*)P_{loan}(D)+(1-F(\theta^R))\pi_L(R_D-1)-\frac{\partial\theta^R}{\partial D}f(\theta^R)\pi_L(R_D-1)D= \left(F(\theta^R)-F(\theta^*)\right)\pi_L L'_{default}(D)+\left(\frac{\partial\theta^R}{\partial D}f(\theta^R)-\frac{\partial\theta^*}{\partial D}f(\theta^*)\right)\pi_L L_{default}(D) \quad (11)$$

When the lender lowers D the benefit is an increased number of borrowers: $\frac{\partial\theta^*}{\partial D}<0$. This is an extensive margin effect. The cost is a higher repossession probability, which comes both from the extensive margin (for every borrower there is a repossession risk) and from the intensive margin, since some borrowers already in the market might now find it optimal to allow the tank to be repossessed in a low-income state: $\left(\frac{\partial\theta^R}{\partial D}f(\theta^R)-\frac{\partial\theta^*}{\partial D}f(\theta^*)\right)>0$. This change along the intensive margin is the treatment effect. Also, lower D implies lower interest paid to the borrower on deposit, $R_D D$ and greater interest paid on fund borrowed at the world interest rate, $R_L D$, – these two effects are incorporated into $R'_{loan}(D)$ and $L'_{default}(D)$. Finally, the positive effect of high D on $L_{default}(D)$ is limited, for the lender has to return all the proceedings from tank sale net the principal, interest, and fees to the borrower whenever they have positive equity. In the empirical part of the paper, the lender never faces non-constant cost of default, since in every case of repossession, the borrower had positive equity in the tank.

An alternative way to present the FOC, which will be useful for the empirical investigation, is in the form MRS = price ratio. Assume that $R_D=R_L$. This assumption is in line with the data and highly intuitive, since the opposite would make either attraction of deposits or funds from the world market suboptimal. When the borrower has positive equity, i.e. $D-(1-\delta)C-Q-K_{maxB}>0$ then the FOC will be:

$$\frac{\frac{\partial\theta^*}{\partial D}f(\theta^*)}{\pi_L\left(\frac{\partial\theta^*}{\partial D}f(\theta^*)-\frac{\partial\theta^R}{\partial D}f(\theta^R)\right)}=\frac{L_{default}(D)}{P_{loan}(D)}=\frac{K-K_{maxB}}{Q+C-(R_L(C-D)+R_D D)+\pi_L(R_D-1)D} \quad (12)$$

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

In equating these two factors - marginal cost of default and marginal revenue per borrower - the lender will not, however, consider the welfare effects on inframarginal customers who would have borrowed in any case. These customers will incur cost from an increase in the required deposit. This creates a wedge between the private and social benefits from raising the deposit requirement that will tend to make lenders choose deposit requirements that are too high from a social point of view.

Note that there will be a kink in the lender's profits as a function of D at the point at which D is just sufficient that D plus the resale value of the tank is just enough to cover the outstanding debt on the tank plus interest and late fees plus K_{maxB}. Denote this as D_F. Increases in D up to D_F will improve profits not simply by reducing tank repossession rates, but also by increasing loan recovery in the event of repossession. Increases in D beyond D_F will only improve profits by reducing tank repossession rates. (The countervailing negative effect on profits of losing good customers will be continuous in D assuming no mass points in the distribution of θ_i).

We will now turn to formally state and prove the main result of this section.

Proposition 1. *If the support of the cumulative distribution function $F(\theta_i)$ is such that $\theta^*(D) < \bar{\theta}$, i.e. there are some inframarginal farmers, and assuming that the profit-maximizing D^* is not D_F, i.e. that at the profit maximizing D^* $D^* + K_{maxB} - (1-\delta)C - Q \neq 0$, then the lender chooses deposit requirements that are too stringent from a social point of view, i.e. $D^* > D^{FB}$ where D^{FB} is the socially optimal deposit requirement.*[20]

Proof. Consider the function of social welfare that is equal to the sum of borrowers' utilities and lender's profit:

$$\mathbf{\Pi}(D) + \mathbb{U}_{total}(D;\lambda).$$

If $D - (1-\delta)\theta Q K_{maxB} \neq 0$, then D^* is characterized by the lender's FOC, which implies $\frac{\partial \mathbf{\Pi}(D)}{\partial D}$. As we showed in the previous subsection, all the farmers prefer as low level of deposit as possible: $\frac{\partial \mathbb{U}_{total}(D;\lambda)}{\partial D} < 0$. Hence the derivative of the social welfare with respect to D is negative:

$$\frac{\partial \mathbf{\Pi}(D)}{\partial D} + \frac{\partial \mathbb{U}_{total}(D;\lambda)}{\partial D} = \frac{\partial \mathbb{U}_{total}(D;\lambda)}{\partial D} < 0.$$

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

The intuition for this result is that a marginal increase in the required deposit D harms inframarginal borrowers, and this negative effect is not internalized by the monopolistic lender.

[20] The result can be extended to the case of a menu of contracts such as $\{(Q(\theta), D(\theta))|\theta^* \leq \theta \leq \bar{\theta}\}$, where $\theta^* \geq \underline{\theta}$ is the lower boundary on borrowers' types that can be profitably served by the lender. Similarly to the case of a fixed Q, the lender experiences a second-order loss from marginal changes in $\{D(\theta)\}$; meanwhile, inframarginal borrowers - those who continue to borrow after a change in D - experience a first order gain in utility in the case of a marginal decrease in D. A change in $Q(\theta, D(\theta))$ caused by a change in $D(\theta)$ has second-order effect on the social welfare, for it is simply a transfer between agents of the economy and affects social welfare only through marginal borrowers - those who would have borrowed at a low level of D and/or Q but will not after an increase in D and/or Q and vice versa.

Thus, the level of $\{(D(\theta), Q(\theta))\}$ set by the lender is socially suboptimal.

This can also be seen as an asymmetric information problem of adverse selection.

Above we modelled the case of a monopolist lender, but analogous results hold under competition, consider a model in which there is free entry of lenders, all of whom can borrow at some common interest rate. Lenders compete to attract borrowers by offering a combination of an interest rate and a deposit requirement. Note that all borrowers would prefer lower interest rates and lower deposit levels, but borrowers with low valuations of the tank, who foresee that there are some states of the world in which they might choose not to repay the tank loan, will put higher weight on reductions in deposit amounts relative to reductions in interest rates than will borrowers with high valuation. In this context, the socially optimal level of deposit requirements will generically not be the competitive equilibrium if borrowers have heterogeneous tank valuations. To see this, consider a candidate equilibrium in which deposits were socially optimal. A lender could profitably deviate from such a candidate equilibrium by slightly raising the deposit requirement and lowering the interest rate in such a way that high valuation borrowers who were unlikely to allow their tanks to be repossessed would prefer the new contract while borrowers with lower valuations would prefer the contract offered by other lenders. Such a lender would then generate positive profits and other lenders would generate negative profits. While the existence of competitive equilibria is not assured in this setting, this implies that in any competitive equilibrium, the deposit requirement will exceed the socially optimal deposit requirement

For simplicity and convenience, we wrote the model in terms of deposit requirements, but it could be extended to include guarantor requirements as well. Similarly, although the model considers the case in which the only negative credit outcome is tank repossession, we expect the model could be extended to include a vector of negative outcomes, including late payment. In such an extension the decision maker's FOC for relaxing borrowing requirements would weigh the gains from making additional profitable loans against the sum of the expected cost of each negative outcome times the change in the probability of that outcome.

Note that while our three-period model focuses on the treatment and selection effects, one other effect, which could be termed a “mechanical effect," will arise in practice given the actual implementation of the program over time. In the very last few months of the contract, the lender will be able to recover the remaining outstanding debt using the deposit from the borrower or the funds pledged by the guarantor. This precludes the outcomes of tank repossession or very late loan recovery, independent of the behavior and hence the incentives of the borrower. Thus, the treatment effect encompasses both an incentive effect on repayment behavior and a purely mechanical effect once the borrower has repaid enough funds to bring the principal down to D. This effect will vary with D.

Extending the model to explicitly model farmers' late payment decision would require more time periods. [21]

Finally, we can consider two alterations to the initial assumption about borrowers credit constraints as described in footnote 9. First, if households were not credit constrained, they would invest all their free funds into deposit anyway - in terms of the model, it implies $R_B = R_D$. Hence, we should observe no effect of the deposit requirement on the take-up rate of borrowers who do not default. To see this fact, notice that the inequality defining take-up rate of borrowers with sufficiently high tank valuations, $\pi_L U_{repay}(Y_L, D; \theta_i) + (1 - \pi_L) U_{repay}(Y_H, D; \theta_i) \geq \bar{U}$, does not depend on D. However, this implication contradicts observations in the data: when the lender goes from 100% to 25% deposit requirement, there remains virtually zero default rate, but the take-up rate increases drastically. Second, if some households were credit constraint in a sense that they did not have enough funds to make a deposit,[22] some of the borrowers would have to default whenever the deposit requirement is set below 100%: a negative shock to income, Y_L would inevitable force some borrowers to default, since they would not have sufficient funds to repay the loan. At the same time, there is zero default rate in both 25%- and 100%-deposit groups. The logic above can be easily extended to the case of guarantor requirement. The two observations - mismatch between the data and the two alternative assumptions about credit constraints - provide suggestive justification for our initial assumption about credit constraints.

In contexts in which the government bails out lenders in the event of bankruptcy, then low deposits can create negative externalities on taxpayers so a regulator might want to establish minimum down payment requirements.

[21] We have worked out one such an extension. We add an intermediate period to the model such that borrowers repay the principal and interest payments on the tank over two periods ($t = 2, 3$). This allows us to explicitly model late and early payments. The main insights of this extension are that the probability of early repayment increases with both the required deposit and the level of loss aversion. Also, in most of the cases, an increase in the required deposit decreases the likelihood of late payment. A borrower with a sufficiently high valuation might choose to repay principal early, thus foregoing investment opportunities in order to reduce the chance of repossession in the future. This would occur only for a very narrow range of parameter values because investing and then liquidating the investment in the case of a negative shock would typically be preferable to paying off the loan early, since paying off the loan early only affects ultimate tank ownership when later income plus the liquidation value of investments made with current funds would not be enough to pay off the principal and interest on the tank loan, but would be sufficient to pay off the principal by itself. Since the interest rate is fairly low, this is a narrow window of parameter values. For $\lambda > 1$, early payment becomes a more attractive strategy.

[22] It is worth noticing that this issue is hardly the case in the data, since observed households do in fact have enough assets to pay a deposit. In particular, all of them have cows and could sell some of them to make a deposit/repay a loan.

4 Project Design and Implementation

This section first discusses features of the loan program that were common across treatment arms and then discusses the 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 4000 (about $50 [23]) below the retail price and the SACCO passed these savings on to borrowers. The price of the tank to the farmers was, denoted C in the model, KSh 24,000 (about $320), or roughly 20 percent of annual household consumption in our sample. Borrowers also incurred installation costs for guttering systems and base construction that averaged about KSh 3,400, or 15% of the cost of the tank.

All farmers received a hand-delivered letter with the loan offer, and were given 45 days to make a decision on whether they wanted to take up the loan. All loans were for the same amount (KSh 24,000) and required an up-front deposit of at least KSh 1,000. The interest rate for all loans was 1% per month, charged on a declining balance. Thus $\frac{Q}{C}$ in the model is approximately 24

However processing late payments was labor intensive and consumed most of the SACCOs staff time, so late payments were costly for the lender. The amount due each month was automatically deducted from the payment owed to the farmer for milk sales. If this fell short of the scheduled loan payment, or if the farmer did not sell milk to the dairy over that month, the farmer was required to make the balance of his payment in cash at the cooperative's office.

Debt service represented 8.4% of average household expenditures and 11.4% of median expenditures at the beginning of the loan term.

The default procedures were the same across the loan groups. When a farmer fell two full months of principal (i.e. KSh 2,000) behind, the SACCO sent a letter warning of pending default and providing two months to pay off the late amount and fees. The letter was hand-delivered to the farmer and followed up with monthly phone reminders.

[23] In this paper we use the dollar to Kenyan Shilling exchange rate at the time of the study which was approximately $1:KSh 75. The current exchange rate is approximately $1:KSh 100.

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. To the extent 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. Farmers agreed that if a tank had to be repossessed, administration costs would be deducted, along with outstanding principal, interest, and late fees, from the proceeds of any tank sale. The administrative costs associated with repossessing the tank, including the cost of hiring a truck, staff time and security, cost the SACCO 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 of vandalism from repossession. XX. IPA and the SACCO agreed that the SACCO could not charge borrowers more than KSh 4,000 to avoid the farmer being left a huge debt as a result of taking out a loan; in the model this figure is C_{maxB}.

At the beginning of the study the SACCO and the dairy were parts of the same legal entity called the Nyala Multipurpose Dairy Cooperative society [24]. The cooperative society 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 fee. 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 in the program were randomly assigned to one of four experimental loan groups, two of which were later divided into subgroups. One group of farmers was offered loans with the standard 100% cash collateral eligibility conditions typically offered by the cooperative (and by most other formal lending agents 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. Note that

[24] In 2012 the Kenyan government enacted legislation that forced the dairy and SACCO arms of the cooperative to split into two legal entity. Despite this, the two arms are still tightly linked and are often treated as a single entity

deposits in the SACCO continued to earn the SACCOs standard returns of 3% per quarter. Thus we will take R_D as 3% per quarter. This group will be denoted Group C (for Cash).

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, denoted Group G (for guarantor), 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. 75% of the loan could be collateralized with the tank itself. Comparing this guarantor group with the 25% deposit group isolates the impact of joint liability.

In a final group, denoted Group A (for Asset), 96% of the value of the loan was collateralized with the tank itself and only a 4% deposit was required. Thus in this group, XXX add model notation XXX

In order to isolate the 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. For one subgroup, the terms of the loan were maintained, while farmers in the other sub-group had KSh 5,000 of their deposits waived one month after the deposit was made, leaving them with deposit of KSh 1,000, the same as the farmers who took out loans 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. [25]

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. Similarly, the selection effect for the guarantor requirement is the difference between an outcome variable in the 4% deposit group and in the guarantor (waived) subgroup. The deposit treatment effect is the difference in a variable between the deposit (maintained) and deposit (waived) subgroups; and similarly, the treatment effect of the guarantor requirement on a variable is the difference between the variable in the guarantor (maintained) and guarantor (waived) subgroups. In the model, the selection effect corresponds to the change in both $\theta^*(D)$ and $\theta^R(D)$ following a change in deposit requirement. The treatment effect corresponds to the change in $\theta^R(D)$, keeping $\theta^*(D)$ unchanged.

[25] 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.

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

Administrative data from the dairy cooperative was used to create a sampling frame of 2,793 households that regularly sold milk to the dairy. A baseline survey was then administered to 1,968 households in two waves between the first half of 2009 and the second half of 2010. The 1,116 households in the first wave were resurveyed in 2010 to ensure that baseline information was up to date on all respondents soon before the credit program was implemented.

In March 2010 the first loan offers, randomized across the six treatment arms, were made to a sample of 600 farmers with baseline data. Farmers who were not currently selling milk to the dairy cooperative were excluded from the sample. In May-June of the same year an additional 849 offers were made, and finally 355 offers were extended in September-October. In total 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.[26]

Figure 1 illustrates the contractual repayment periods for loans made in the experiment (although some loans matured slightly later than suggested due to delayed delivery of the water tank).[27]

In mid-2011 a midline survey was administered to all households in our sample, in part to check that tanks had been installed and were in use, but also to collect data on real impacts, including school participation and indicators of time use, based on asking what every household member did in the 24 hours prior to the survey. Subsequently in 2011 and 2012 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,[28] while detailed production data was elicited from households in the 4% deposit group and the 100% cash collateralized group. [29]

[26]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

[27]When a household entered into a loan agreement, a water tank was delivered within a period of three months.

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

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

Finally, administrative data from the dairy cooperative was used to construct indicators of loan recovery, repossession, and late payment, collection actions [30], and early repayment. 460 farmers took out loans. Data on loan recovery and tank repossession is available for all borrowers, and detailed data on the timing of repayment is available for 456 of the 460 borrowers.

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 if assignment was indeed random.

In part using the proceeds from the first set of loans, another 2616 farmers were offered loans between February and April 2012 (following a baseline survey in December 2011) made, providing an out-of-sample test. These loans 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, but not the ??tracking?? of payment .

These farmers were randomly assigned to receive loans 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 loans but, because the loan 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 in this out-of-sample group.

5.2 Empirical Approach

Our empirical specifications reflect the randomized assignment of loan types across the sample.

Our regressions typically take the form:

$$y_i = \alpha + \beta_A A_i + \beta_D^M D_i + \beta_D^W D_i^W + \beta_G^M G_i + \beta_G^W G_i^W + \varepsilon_i \tag{13}$$

where y_i is the outcome of interest, A_i, D_i^M and G_i^M are dummy variables equal to one if individual i is in 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

[30] e.g. receipt of a letter warning of pending default or reclamation of security deposit

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 farmers who take up loans in the 4% deposit group due to differential selection.

Note that in the model we have presented above, the loan take up rate corresponds to $1 - F(\theta^*(D))$ and the repossession rate corresponds to $\frac{F(\theta^R(D)) - F(\theta^*(D))}{1 - F(\theta^*(D))}$.[31] Effects of changing the required deposit D, which we empirically estimate, correspond to changes in the relevant cutoff values. The selection effect corresponds to changes in $\theta^*(D)$ while the treatment effect corresponds to changes in $\theta^R(D)$.

The repayment propensity of marginal farmers who are induced to borrow so by being offered a 4% deposit requirement rather than a 25% deposit requirement is equal to the difference in outcomes between the 4% and 25% deposit (waived) group, divided by the fraction of borrowers in the 4% group who would only borrow if in that group, e.g., the difference in loan take up rates between the 4% and 25% groups, divided by the take up rate in the 4% group. This corresponds to $\frac{F(\theta^R(6{,}000)) - F(\theta^R(1{,}000))}{[F(\theta^*(6{,}000)) - F(\theta^*(1{,}000))]/[1 - F(\theta^*(1{,}000))]}$ in the model.

The treatment effects of borrowing requirements are identified by comparing loan repayment outcomes for borrowers who have the borrowing requirements maintained with loan repayments for borrowers who have borrowing requirements waived ex post. That is, any treatment effect of the deposit requirement would show up in a difference between β_D^M and β_D^W, while a treatment effect of the guarantors would be observed if β_G^M and β_G^W differed. The treatment effects of the deposit requirement would encompass the incentive effects of borrowing requirements in the model. Specifically, as the required deposit D decreases the cutoff value $\theta^R(D)$ falls. The effect of moving from $D = KSh\,6,000$ to $D = KSh\,1,000$ corresponds to $F(\theta^R(6,000)) - F(\theta^R(1,000))$ in the model.

In practice, the empirically minded treatment effect will reflect not only incentives that borrowing requirements create for borrower behavior, but also the mechanical effect of the deposit and guarantor requirements. For example, borrowers in the 25% deposit (maintained) group and in the 25% deposit (waived) group who each make the first 21 months of payments on

[31] This is a assuming that there are in fact cases of repossessions, i.e. that $\theta^R(D) \geq \theta^*(D)$. The repossession rate cannot be negative. If $\theta^R(D) < \theta^*(D)$ then the repossession rate is zero.

schedule and then cease making any other payments will have different tank repossession outcomes because the lender would cover the balance using the deposit for the borrower in the deposit (maintained) group and the proceeds from a tank repossession in the deposit (waived) group. To take another example, differences in late payment in month five between the 25% deposit (maintained) and 25% deposit group could reflect both differences in repayment incentives and differences in liquidity associated with having assets tied up in an illiquid deposit. Although it is difficult to decompose the treatment effect into incentive and mechanical effects, we can distinguish these treatment effects from the selection effects which generate a wedge between profit-maximizing and social welfare maximizing borrowing requirements.

Finally, we estimate real impacts by comparing outcomes in the 100% cash collateralized group, Group C, and the 4% collateral group, Group A, exploiting the large difference in take up rates between these two groups:

$$y_i = \alpha + \beta_A A_i + \gamma X_i + \varepsilon_i \tag{14}$$

This equation estimates the ITT effect of the difference in loan offers. (If one is willing to make the assumption that loan characteristics, such as the possibility of repossession (which characterized Group A loans, but not Group C loans) did not directly affect household and farm outcomes, then this could be used to create an IV estimate of the impact of tanks.)

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 on observable borrower characteristics.

6.1 Impact of Borrowing Requirements on Loan Take Up

Our first finding is that many farmers are credit constrained — they would like to borrow at the interest rate offered by the SACCO but are prevented from doing so by restrictive borrowing requirements. In the original sample, 2.4% of farmers borrow under the standard SACCO contract with 100% cash collateralization; 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; and 44.3% borrow when 96% of the loan can be collateralized and only a 4% deposit is required (See table 4). This implies that more than 40% of 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.

The take up rates in the out-of-sample group are broadly comparable to those in the original experiment (Table 4). 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 of the loans, or to some unusual period-specific circumstances.

Our second finding is that joint liability does not substantially increase credit access relative to individual liability. In the original sample, 27.6% of farmers borrow when they have to put up a 25% deposit themselves, 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 (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 they 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.

In any case, joint liability did not expand credit access in our context. The high elasticity of loan take up to the ability to collateralize loans with purchased assets and the low responsiveness to joint liability points to a potential limitation of traditional joint-liability based microfinance and suggests that addressing barriers to asset collateralization, such as weak contract enforcement, may play an important role in addressing credit constraints.

6.2 Impact of Borrowing Requirements on Borrower Characteristics

Do different borrowing requirements select borrowers with different wealth levels or other differences in observable characteristics? 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 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,[32] we observe statistically significant differences at

[32] $3! = 6$ pairs for each of 14 variables,

the 5% level in just four, almost exactly what would be expected under the null hypothesis of no selection on observables. (Specifically, borrowers in the 4% deposit group, had lower log household assets than those in the 25% collateralized group, had lower log expenditures than those in both the deposit and guarantor groups, and were less likely to own a water tank than those in the 100% cash collateralized group.)

Perhaps surprisingly, there is little evidence that strict deposit and collateral requirements select borrowers who are substantially richer than less strict requirements. Borrowers in the 100% cash collateralization arm do not have particularly high assets or expenditures (however, there are large standard errors.)

The starkest difference between farmers in the 100% cash collateralized group who chose to borrow and farmers in other arms who chose to borrow is that under the 100% cash collateralized arm, farmers 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. Relaxing borrowing requirements induced non-tank owners to buy tanks.

We do find that borrowers tended to have more assets, higher per capita expenditure, more milk-producing cows, and more years of education, than non-borrowers.[33]

XX Is this right? XX Under the model, those with higher valuations of the tank will be more likely to borrow. This could include those with more wealth or education and thus a greater value of time and those with more cows. Wealth will not have a direct effect by relieving credit constraints as long as farmers have access to investments yielding the same rate of return. XXX

7 Loan Repayment

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

7.1 Loan Recovery and Tank Repossession

Perhaps our most striking repayment result is that all loans were fully recovered, along with all interest and late fees, and that rates of tank repossessions were very low. There was one tank

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

repossession in the original sample, and two more in the out-of-sample group, all of which took place in the 4% deposit group. In one out of those three cases the borrower paid off arrears after the tank had been repossessed but before it had been sold and reclaimed the tank. [34] The two tanks that were repossessed and then sold were purchased at prices sufficient to pay off the borrowers remaining debt (KSh 29,000 and KSh 22,000) [35]

Aside from the small 100% cash collateralized group, 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 loan non-recovery and tank repossession outside the 4% group (and even within it). It is clearly impossible to use asymptotics based on the normal distribution when we observe zero or close to zero tank repossessions and loan non-recoveries 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 confidence intervals for the rate of tank repossessions and loan non-recovery under the point estimates for each loan type. The tank repossession and loan non-recovery rates include loans from both the original sample and out of sample groups. 95% confidence intervals were calculated using the Clopper-Pearson exact confidence interval for binomial distributions (Clopper and Pearson, 1934).

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 $\sum_{E=0}^{E} \binom{E}{n}(1-p)^{n-E}(p)^{E}$.

The upper limit of the confidence interval is calculated by solving for p in $\sum_{E=0}^{E} \binom{E}{n}(1-p)^{n-E}(p)^{E} = \frac{\alpha}{2}$, where α is the significance level.

Likewise, the probability of observing E or more events is given by $\sum_{E=E}^{N} \binom{E}{n}(1-p)^{n-E}(p)^{E}$.

The lower limit of the confidence interval is calculated by solving for p in $\sum_{E=E}^{N} \binom{E}{n}(1-p)^{n-E}(p)^{E} =$

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

[35] 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

$\frac{\alpha}{2}$.

If there are zero events, the lower limit of the confidence interval is zero. In this case, we use a 10% significance level ($\alpha = 0.05$) for the upper bound.

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 good a good approximation when the probability of an event is close to zero given our sample size) we used Fisher's exact test to test for a difference between the repossession probability.

To see the intuition, note that if the true repossession rate were the same in the 4% group and the combined 25% group, then conditional on observing three repossession events, the odds that all three events would be in the 4% group would be equal to the fraction of borrowers in this group cubed, or $(431 \times 430 \times 429)/(1149 \times 1148 \times 1147) = 0.0525$. So we can almost, but not quite, reject at the 5% level that the probabilities are the same. 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 loan non-recovery and tank repossession, since loan non-recovery and tank repossession rates did not budge off of zero when deposit or guarantor requirements were waived ex post, but there is evidence of selection effects, since tank repossession was positive (albeit low) in the 4% deposit group.

7.2 Late Payment

Table 6 presents late payment results for the 456 borrowers in the original sample for whom we have complete repayment data. Columns (1) to (3) report late payment outcomes during the loan cycle and columns (4) to (6) show payments that were late at the end of the two-year loan cycle. The memo items below show the p-values on the existence of the selection effect that will drive wedges between private and social optima under the model, as well as on the treatment effects. We first discuss overall effects and then selection and treatment effects.

There is evidence of “overall effects“ of different treatments. This is most dramatic in comparing the 4 percent deposit arm and the 100 percent cash, collateralized arms. Those offered 100% cash collateralized loans are much less likely to be ever late than those in any other group, with point estimates of the difference ranging from 43 to 59 percentage points. Moving from a 100% cash collateralized loan to a 96% asset collateralized, 4% deposit loan also reduces issuance of pending default letters, and it reduces late balances at the end of the loan cycle by KSh 222, or about \$3. None of the ten 100% collateralized loans were late at the end of loan. This is significantly less than in the 4% deposit arm, but not than in the 25% deposit or guarantor arms. The extent to which loans were late, however, is tiny, as shown in Column (5) of Table 6, which reports the outstanding late balance at the end of the contractual loan period. Point estimates of the average late balance varied from 46 to 297 KSh, or less than one percent of the loan value. Mean months late in the other groups varied from 0.08 to 0.22 months, or 2-7 days. Since the administrative cost of dealing with late repayments very likely exceeds the value of late fees paid to the lender, and since a higher rate of late payment may well signal a set of borrowers who are more likely to fail to repay, and since the profit on each loan is likely very small a profit maximizing borrower might well prefer strict borrowing requirements. The large differences in "late ever" between the 100% cash collateralized arm and the 4% deposit arm presumably creates costs for the lender that, while small relative to the absolute value of the loan, may be significant relative to profits on loans that are repaid on schedule

There is some suggestive evidence, significant at the 10% level, that stricter deposit and guarantor requirements select borrowers who are less likely to be ever late (Table 6, column 1). To see this, note that the 25% deposit requirements selects borrowers who are 11 ($57 - 46$) percentage points less likely to be late at least once than the 4% deposit loan. Similarly, imposing a guarantor requirement leads to borrowers who are 14 ($57 - 43$) percentage points less likely to be late ever. Assuming that the cost of sending out late notices exceeds the late fee, or that late repayments signal lower tank valuation and greater repossession probability, this will drive the lender to choose stricter borrowing requirements than the social planner. So the treatment effect goes in the "wrong "direction, suggesting a potential wedge between privately and socially optimal deposits.

We find no significant treatment effect of either the deposit or guarantor requirements on being ever late. Point estimates suggest that any incentive effect of maintaining deposits in increasing repayment incentives and thus reducing the incidence of ever being late is outweighed by the mechanical effect of waiving these requirements in freeing up liquidity, thereby improving the ability of farmers to make repayments.

For other repayment outcomes, shown in other columns, there is little evidence of a selection effect. Column (2) reports whether a lender received a pending default letter at some point in the loan cycle (which was typically sent when a farmer was at least two months in arrears). There is no evidence of treatment and selection effects for the deposit group. There is only a borderline significant negative treatment effect of requiring a guarantor ($p = 0.10$). According to column (3), 11 percent of borrowers had security deposits reclaimed, with no significant differences between the treatment arms and the 4% deposit groups. We cannot reject the hypotheses of no treatment effect and of no selection effect.

Turning to outcomes at the end of the cycle, which are likely to be heavily influenced by the mechanical effect, since deposits remaining near the end of the loan cycle can be used to pay off the loan, we see evidence of treatment effects in columns (4)-(6), but not much evidence of selection effects. Repaid late is a dummy variable equal to 1 if at the contractual maturity date the borrower has an outstanding balance left to pay. Column (6) in Table 6 shows the number of months by which full repayment of the loan was late (any farmers who paid early are counted as being zero months late.). There are significant treatment effects from the 25% deposit on "repaid late" and "months late." Waiving the deposit increases the chance that borrowers are late at the end of the loan cycle by about 10 percentage points and increases the time by which loans miss the two-year end of the loan cycle by 11% of a month, or just over 3 days. This seems likely to be a mechanical effect. However, since the magnitudes are small, with the difference in the late balance less than 2 USD, these late balances themselves are unlikely to have a major impact on the profitability of lending. There is no evidence for treatment effects of guarantors on late payment outcomes.

7.3 Calibration

Armed with the results above, and with the first order condition for profit maximization, we can conduct a rough calibration.

So far we have focused on the average rate of loan recovery and tank repossession in each group, but as the model's FOC for lenders makes clear, the lender's decision about what deposit to set will depend on the ratio of the marginal repossessions associated with a change in D to the marginal loan take up rate. To calculate the marginal repossession rate in the combined sample from moving from 25% loans to 4% loans, i.e. D decreasing from $D =$ KSh$6,000$ to $D =$ KSh$1,000$, note that the average repossession rate is 0.7% for 4% deposit loans, $F(\theta^R(1,000)) - F(\theta^*(1,000)) = 0.007\%$, and zero for 25% loans (Table 5, column 2), $F(\theta^R(6,000)) - F(\theta^*(6,000)) = 0\%$. The take up rate for 4% deposit loans is 41.89%. For 25% deposit loans, the combined sample take up is 23.93%. Thus $\frac{(F(\theta^*(6,000)) - F(\theta^*(1,000))}{)} / F(\theta^*(6,000)) =$ $(41.89 - 23.93)/41.89 = 42.9\%$ of the people 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% of the marginal loans made would lead to a repossession. To put this another way, one out of 62 marginal borrowers will have a tank repossessed.[36] Whether a lender would prefer the low deposit depends on whether the

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

marginal profit for an extra loan is more than 1/62nd as much as the repossession costs that the lender bears $C^T K - CK_{maxB}$.

In our context, the additional profits to the lender from a successful loan are likely extremely small given the low real interest rate, so it seems plausible that a profit-maximizing lender would not lend with only a 4% deposit requirement. The social planner will also take into account the benefits to the inframarginal borrowers of a lower deposit requirement. For every marginal borrower there are $(100-42.9)/42.9 = 1.33$ inframarginal borrowers. This implies that for every marginal loan repossession there are ($62 \times 1.33 = 82$) inframarginal borrowers who each have to pay KSh 5,000 in additional deposit if the lender moves from a 4% deposit to a 25% deposit. If R_B is 25% per year, or 50% over the two-year life of the loan and R_D is 3% a quarter year or 246% over the two year life of the loan, the 82 inframarginal borrowers would give up a total of KSh 106,600192,700 in earnings on the alternative investment over the interest rate they earn on their SACCO deposits.[37] It thus seems plausible that it would not be profit maximising for the lender to reduce the deposit from 25% to 4%, but that it would be socially optimal to do so.

Note that the SACCO requires 100% cash collateralization, and that this is well above the level that would ensure full recovery of the loan, so the conditions of Proposition 1 that $D^* \neq D^{FB}$ is satisfied, and hence we can conclude that under the model the socially optimal deposit would be less than the 100% cash collateralization chosen by the SACCO.

One can attempt to draw some inferences about the lender from observing that changed its policies to allow 25% collateralization after learning about the results of the program. Since the lender is a cooperative, it therefore might potentially make some loans that do not contribute to profits if they are welfare maximizing. Whether it would do so depends on how decisions are made in the cooperative, so we cannot draw definitive conclusions about whether allowing 25% loans generates greater profits than only allowing 100% cash collateralization. However, the fact that even after the results of the experiment were revealed, the cooperative did not lower the borrowing requirement to 4%, suggests that this was not seen as profit maximizing, since if it were profit maximizing, it would have been in the interest of all farmers to lower the deposit to 4%.

An alternative factor that will affect the profitability of loans is late payment, with late loans incurring additional administrative costs. The data shows that changing deposit requirements affects the quantity of late repayment and hence, the profit maximising deposit requirement will reflect how changes in D affect late repayment. In particular, our study found that 100% cash

[37]The additional KSh 5,000 deposit made by the 82 marginal borrowers would have earned 50% interest, KSh 2,500 per person, but instead earn KSh 150. Hence each of the 82 inframarginal borrowers forgoes KSh 2,350 of earnings, a total of KSh 192,700 across all of the inframarginal borrowers.

deposit had less late repayment across all late repayment measures.

Outside of the study, loans conducted by the SACCO incur large administrative costs on late loans. On late loans, staff have to calculate by hand the amount the borrower is in arrears including the principal, interest and a penalty fees due. Staff then calls late borrowers to tell them they are late and how much they must repay. Borrowers who are behind on repayments are then called to tell them by how much they are behind and when they need to repay by. Using information from interviews with SACCO staff and costs data from the SACCO we estimate the cost of dealing with a late loan is approximately 25 times higher than dealing with a loan that is on time or ahead of schedule.[38] Hence, the SACCO may set high deposit requirements to ensure low late repayment even if increasing deposit requirements has negligible effects on default rates.

To evaluate the importance of late repayment for the optimal deposit requirement we must calculate the cost of late repayment. The SACCO spends approximately 80000 KSh on collecting loan repayments of which there are approximately 3700 a month. Hence, collecting each monthly repayment costs an average of 22 KSh with a loan that is late in a given month costing 95 KSh to administer and a loan that is on time costing 4 KSh to administer.[39] Hence the marginal administrative cost of a loan that is late in a given month is $(95 - 4)$ 91KSh. If one just considers borrowers that are late at least once we can see that compared to the 100% group an additional 46% of people in the 4% loan were late at least once. Just considering the cost of borrowers first month late one can make a lower bound estimate that the additional lateness cost the lender at least (0.46×91 KSh) 44 KSh.

One can consider the relative importance of late repayments compared to defaults by also calculating the cost of default. Our point estimates show that when changing from 100% to 4% deposit the default rate rose by 0.7%. The cost of a default to the SACCO ($C^T - C_{maxB}$) was 4700 KSh which meant the expected increase in default costs per loan was (0.007 times 4700) 33 KSh per loan. Hence, we find that reducing the deposit requirement from 100% to 4% increases expected default costs by 33 KSh and the expected cost of lateness by at least 44 KSh. This suggests that the change in late repayment is a crucial factor in determining the lenders and the socially optimal deposit requirement. Indeed, it is possible that late repayment explains why the

[38]19.5% of the SACCOs loans are currently late and SACCO staff estimate they spend 85% of their time on loan recovery on late loans. $(0.85/19.5)/(0.15/80.5) = 23.4$ However, it should be noted that this calculation is sensitive to the staffs estimate that they spend 85% of their time on loan recovery on late loans. If instead we assumed that staff spent 90% of their time on late loans rather than 85%, then we would estimate that dealing with a late loan would be $(0.9/19.5)/(0.1/80.5) = 37.1$ times as costly as dealing with a loan repaid on time. Thus, when taking into account the uncertainty in self-reported estimates we can only give very rough calibrations about the importance of late payment.

[39]Using 22 KSh = (proportion of late loans times cost per late loan) plus (proportion of on time loans times cost of on times loans) and that late loans are 23.4 times as expensive to administer. $22 = 0.195 \times Cost_{Late} + 0.805 \times Cost_{on-time}$ and $Cost_{Late} = 23.4 Cost_{on-time}$

lender did not offer borrowers lower deposit rates despite the low default rates and increased take up.

We can also consider the effect on costs due to late repayment going from a 25% deposit to a 4% deposit by comparing lateness in the two treatment groups. Our data does not indicate a clear difference in late repayment 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% loan and the other three indicate there was greater lateness in the 4% loan. Hence, the data indicates there is not a large difference in costs of late payment incurred in the 4% and 25% cash collateralized groups.

In the asset-collateralized tank loans the SACCO has begun to offer the SACCO has changed its penalty for late repayment. For other loans the SACCO charges a standard interest rate depending on the principal balance of the loan, a standard interest rate and an additional penalty interest rate on the late balance if a borrower is behind on their payments. For late loans SACCO employees have to calculate by hand the amount borrowers were in arrears. The new asset-collateralized tank loans require borrowers to have repaid a fixed amount after each month and do not charge interest or penalty fees dependent on how much has been repaid. This repayment mechanism was introduced in part because it makes calculating the arrears quicker and so makes late repayment cheaper. This effort to reduce the costs of late repayment may be a response to the higher late repayment observed late repayment in the asset-collateralized loans compared to the 100% cash collateralized loan.

The fact that all the 4% deposit loans were fully recovered, had only a 0.7% default rate and yet do not appear to be profit maximizing may be explained by high administration costs and late payment. We estimate that the cost of marketing and delivering a loan administration is approximately KSh 1,490 . This figure is high compared to the size of the loan and reflects the labor intensive methods used by the SACCO to market loans and handle loan late repayments. While a computer system was used by the SACCO to make transactions, staff often had to calculate by hand required monthly payments and late fees due from borrowers. With real interest rates close to zero it may be that loans that were repaid on schedule earned the lender little profits compared to the losses on loans which were late or had repossessions. Thus, even if they have a low propensity to default, the costs of attracting marginal borrowers may outweigh the benefits and retaining stringent deposit requirements may reduce the lenders profits.

8 Early Repayment

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, one might imagine that few farmers would repay early, since doing so would amount to foregoing a close to zero interest loan. In fact, however, early repayment was common, as indicated in Figure 2 and Table 7. Column (2) in table 7 reports an indicator of "months early" where any farmer who paid late is counted as having paid zero months early. Column (4) reports months of low-interest loan foregone by repaying early. This is equivalent to column (4) minus the non-waived deposit. Under the standard savings and credit cooperative contract, 90% of people in the 100% cash collateralized group repaid their loan early. On average, they were 15 months early on a 24 month contract. Even setting aside the eight months of principal in their deposit, they forewent seven months of low interest loan. Figure 2 illustrates the distribution of months to repay across the program arms.

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.

As illustrated in Figure 2, payment after 19 months is more common in the 25% deposit (waived) than in the 25% deposit (maintained) group. People in the deposit waived group are thus giving up several months of a low interest loan.

Point estimates suggest that having a deposit required and then waived has a treatment effect on early repayment. This could arise fairly naturally with reference dependent preferences. To see why point estimates suggest a treatment effect, note that only 12.5% of those in the 4% deposit group paid off their loan within 19 months (see Figure 2). Recall that 44.3% of households take up loans in the 4% deposit group and 27.6% of households take up loans in the 25% deposit group. Assuming that any household who takes out a loan under a 25% deposit condition would also do so under a 4% deposit condition, 62% of those who take out loans in the 4% deposit group would have taken loans in a 25% deposit condition and 38% would not have taken loans in the 25% deposit condition. 39.7% of those in the deposit (maintained) group did so. The 25% deposit (waived) group's early repayment behavior looks much more like that of the 25% deposit (maintained) group than that of the 4% borrowers. 28.3% of those in the deposit (waived) group paid off fully after 19 months.

To take the best possible case for this being the selection effect, consider the extreme assumption that none of the people who would have borrowed only under the 4% loan condition would pay off early. Under this assumption, if there were no treatment effect and only a selection effect, 28.3% of the 62% of those in the 4% deposit condition who would have borrowed under the 25%

loan condition would pay off after 19 months. So $28.3\% \times 62\%$, or 17.55% of borrowers under the 4% deposit arm would have paid off after 19 months. In fact, only 12.5% of those borrowing under the 4% deposit arm paid off after 19 months, suggesting a treatment effect of having the deposit initially required and then waived on early payment. While point estimates suggest that this could not be explained by selection, taking into account standard errors, from a treatment perspective we cannot reject the hypothesis that there is no treatment effect of deposit waived compared to never having had a 25% deposit.[40] From a Bayesian perspective, the data should shift priors in the direction of a treatment effect.

Why do people who have their deposits returned to them pay off their loans early rather than use the extra months of low-interest loans for another purpose? One could tell a number of stories and in fact an extension of the model to accommodate multiple repayment periods, can generate a narrow range of the parameter space in which loans are repaid early, although not a treatment effect of first requiring and then waiving a deposit. It is worth noting that under reference dependent preferences, people will become attached to keeping the tank, so the range of parameter values for which they repay early will expand (Kahneman and Tversky 1979). Moreover, under reference dependent preferences, if a farmer is induced to make a deposit in the SACCO by having a deposit required, and then waived, and if this changed their reference point, so they thought of the funds as being for the tank purchase, they would be more likely to keep funds allocated to that purpose.

Prospect theory could 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.

In summary, prospect theory could generate many of the patterns we see in the data: 1) low take up of loans with high deposit requirements; 2) high take up of loans collateralized by assets purchased with the loan; 3) high repayment rates of asset collateralized loans; 4) widespread early repayment; and 5) earlier repayment of loans by those randomly assigned to the arm in which a 25% deposit requirement was required but all but 4% was later waived than by those randomly assigned to the group with 4% deposit; and 6) a concentration of take up of 100% cash collateralized loans among farmers who already owned tanks and thus may have seen purchasing a new durable tank as a way to guard against loss of an existing asset.

[40] Many farmers immediately paid off their remaining balances once they reached a level that could be covered by the deposit.

9 Real Impact of Loans

While the focus of this paper is on credit markets, it is worth noting that the expanding access to credit had real effects on access to water and time use, consistent with Devoto et al. (2011), as well as with a broader literature on the role of credit in technology adoption. There is also evidence in differences (albeit not levels) of effects on girls schooling. While the evidence is not dispositive it also does not suggest borrowers are paying off tank loans with additional income generated by the tank. We find no significant effects on milk production, but also cannot rule out substantial effects. (Note that our model is not reliant on the assumption that water tanks generate increases of income.) There is some evidence that expanded credit access leads households outside the top of the distribution to sell more milk to the dairy during the period of loan repayment, consistent with the hypothesis that they are doing so to repay their loans.

The results we present in this section are intent-to-treat estimates comparing real outcomes for the "treatment group" (households offered 4% deposit loans) with those for a comparison group (either households offered the 100% cash collateralized loans, for which we have multiple rounds of survey data, or all other groups, for which we have administrative milk sales data).

In Table 8, we present ITT estimates of the impact of assignment to the 4% deposit group as opposed to the 100% cash collateralized group, on tank ownership and capacity, cow health, and milk production. The survey data were collected in a series of rounds from November 2011 to September 2012. 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, due in part to variations in rainfall conditions over time.

Assignment to the 4% deposit group rather than the 100% cash collateralized group 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 increased average log-capacity by about 10% (i.e., an increase in volume of about 60 percent). 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 the 4% deposit group and the 100% cash collateralized group is much greater than 27%, it seems that while loans clearly had real impacts the loans partially crowded out investments that would have been made otherwise. We do not see significant increases in total household assets (not reported). This is consistent with the model, however, since households that do not purchase tanks will make alternative investments.

Table 8, column 4, suggests provision of water tanks reduced sickness among cows. However, it is worth noting that there were baseline differences in cow health (as reflected in the coefficient on treatment in this column), so it is conceivable that this in part reflects mean reversion. 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.

We see no evidence of a change in milk production in levels in column 5. 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), and this effect would not show up in levels rather than differences.

Table 9 shows the impact on milk sales based on monthly administrative data from the dairy on farmers in all arms of the study. It compares the 4% deposit group to all other groups using an ITT approach. There is some evidence (significant at the 10% level) that farmers offered four percent deposit loans are more likely to sell milk to the dairy. Assignment to the 4% deposit group does not significantly affect the volume of sales (column 2 and 5). However, there is some evidence of an effect outside the top five percentiles. The treatment effect on trimmed sales is significant at the 10 percent level (Column 3). However, again, the effect would not be present in levels. The strongest evidence for an effect of the tanks on the intensive margin of sales comes from column 6. If one trims the top 5% of observations, milk sales are greater in the treatment group in the period before loan maturation, (although again this effect shows up only in differences, not in levels). The data are consistent with the hypothesis that households outside the top of the distribution sell more milk to the dairy to help pay off their loans and that some households which might not have sold milk to the dairy otherwise do so as a way to pay off the loan.

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 and16. 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 and insignificant effects for girls (Columns 1 and 2, respectively). Access to credit for the purchase of tanks allows females in treatment households to make up nearly all of the gender differential (point estimate -2.22 minutes per day per female, column1, row 1) in time spent fetching water, significant at the 10 % level. Access to credit to purchase water tanks reduces girls' time tending livestock by 12 min/day in households with piped water. In households without piped water, it reduces boys' time tending livestock by 15 min/day.

There is some evidence of effects of access to credit on girls' schooling (Table 11), albeit only in differences. 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 4 percentage points or 4.3% over a counterfactual of $0.925 = 0.984 - 0.047 - 0.012$.

Overall, the data seem broadly consistent with the idea that the ability to collateralize loans for water tanks improves households' access to water and saves time, some of which may have gone into human capital accumulation.

10 Conclusion

In high-income countries, households can often borrow to purchase assets such as property or equipment 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. 44% of farmers were willing to borrow 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 only about 5% as many (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. 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 model suggests that profit-maximizing deposit requirements for lenders will be greater than socially optimal deposit requirements if high deposit requirements select more profitable borrowers. We find that even with only a 4% deposit, all loans were fully recovered and only 0.7% of loans led to a tank repossession. Nonetheless, tight borrowing requirements reduced costs for the lender associated with tank repossession and with late payments. A Karlan-Zinman approach to decomposing this effect into a treatment and a selection effect finds that stricter borrowing requirements select borrowers who are less likely to experience tank repossessions and who are less likely to be late at least once in making loan payments.

The first order condition for profit maximization requires that at interior solutions, increases in stringency of borrowing conditions balance the cost of losing marginal profitable customers against the gain from losing unprofitable marginal customers. A rough calibration of the first order condition suggests that despite the lender fully recovering its principal and interest, administrative costs of dealing with repossessions and late payments are high enough, and profits from good borrowers are low enough, that we cannot reject the hypothesis that requiring only 4% deposit is welfare maximizing but not profit maximizing. There is, however, reason to believe that the initial requirement that 100% of the loan be collateralized with pre-existing financial assets, was tighter than would be profit maximizing. After the end of the external support from the program from IPA, the Nyala SACCO decided to establish a program on its own. The loans require a 25% deposit from the borrower. Loan terms are in line with other loan products offered by the SACCO. To date 152 loans have been issued and there have been no defaults. It should be noted that the SACCO has now introduced an appraisal fee on all of it's loans to help cover administrative costs. For the tank loan this is equal to KSh 700, equivalent to raising the monthly interest rate borrowers pay by 0.2 percentage points.

We find that lower borrowing requirements are associated not only with increased borrowing, but with the real outcomes of greater household access to water, time savings, and, in some specifications, greater school enrollment for girls. Our results also suggest that barriers to collateralizing loans with assets purchased under the loan may substantially reduce investment in new technologies that require substantial capital outlay.

It is certainly possible that shocks to income might be correlated across borrowers due to aggregate shocks, such as droughts or changes in output prices; that in bad states of the world repossession rates might have been higher; and that although we have a large sample of loans, the sample of states of the world is insufficient to rule out the possibility that bad states of the world are frequent enough that in expectation lending with lower borrowing requirements would be unprofitable. However, our argument is not that lenders are failing to optimize, but rather that strict borrowing requirements select more profitable borrowers, borrowing requirements will be greater than socially optimal. Climate conditions were fairly typical during the initial phase of loans and during the out of sample test. It seems likely that if there were a bad state of the world, some borrowers who were late under typical conditions would have experienced tank repossessions, and some tank repossessions would have led to less than full loan recovery for the lender, so that the tendency of high deposit requirements to select more profitable borrowers would be even stronger.

Our calibrations highlight the critical role of administrative costs relative to the profit margins on successful loans in determining profit-maximizing borrowing requirements. Even though the lender fully recovered principal and interest for all the loans, our calibrations suggest that high borrowing requirements might be profit maximizing , simply because lenders incur greater expenses when borrowers make late payments or their tanks have to be repossessed. Lenders in the developed world have highly automated procedures for dealing with late payments, but the SACCO's procedures were extremely labor intensive and expensive relative to loan value. Differences in productive efficiency and thus in administrative costs relative to loan value may partially account for differences in borrowing requirements between low and high-income countries. Adoption of better ICT technology could potentially radically lower the cost of handling late payments. Payments to farmers could be made and recorded electronically and receipts and transfers could be done by mobile phone. 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 therefore be welfare improving, and it would be a relatively easy, low-cost, and politically non-controversial step to reducing transaction costs, and potentially encouraging lenders to relax borrowing requirements.

More fundamentally, lenders in developing countries may be reluctant to make collateral-based loans due to weak property rights and/or contract enforcement, and even though in our context, the lender experienced no problems repossessing collateral, our context was a relatively favorable one, and in other contexts, improving property rights or contract enforcement may play an important role in facilitating collateralization of loans with assets purchased with the loan.

There may be strong explicit or implicit pressures on lenders to keep down interest rates, late payment fees, and repossession charges. The model suggests that this will lead them to impose stricter borrowing requirements, and our data suggests that this may dramatically reduce credit access. To the extent that low-income countries face a higher ratio of administrative costs to loan value than developed countries, requiring interest rates, late fees, and repossession charges to be similar to those in high-income countries will lead to stricter borrowing requirements.

Note, however, that the factors discussed above all relate to the lender's choice of borrowing requirements, and the model suggests that in the presence of the selection effects we find there will be a gap between the profit-maximizing and social-welfare maximizing deposit requirements. This suggests a possible role for savings and credit cooperatives. As noted earlier, savings and credit cooperatives are a very widespread institution in Kenya. They also played an important role historically in several currently developed countries. Our analysis suggests a possible explanation. If there are indeed large social gains to inframarginal borrowers from reducing borrowing requirements but profit-maximizing firms serve the marginal borrower, then savers who anticipate a probability that they may want to become borrowers at some point may wish to join savings and credit cooperatives that promise to allow those who have accumulated sufficient savings to borrow under requirements that are somewhat less tight than would be profit maximizing. They would also vote for such terms. Commercial lenders have so far shown little interest in extending credit for tank loans, and arguably a purely profit maximizing borrower would not serve the SACCO customers at all and the SACCO could earn higher returns simply investing its funds commercially rather than making loans to members, so while we cannot reject the hypothesis that the SACCO is profit maximizing, we also cannot reject the hypothesis that it is influenced by the preferences of SACCO members who see themselves not just as savers, but as potential borrowers. Of course a non-profit maximizing lender may have difficulty attracting savings from outside the cooperative. Socially-minded investors might be willing to lend to SACCOs that could in turn lend to members with deposit requirements that are lower than would be profit maximizing.

The market failure identified in the paper creates a potential case for policymakers to encourage less restrictive borrowing requirements by subsidizing such loans. Of course there is also danger of government failure with such subsidies turning into favors for the politically connected and possibly triggering a need for bailouts 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.

To the extent that there are learning spillovers to other organizations, there may be a case for subsidizing experimentation. In fact, a major commercial bank in Kenya (Equity Bank) now has started a program with another tank manufacturer in which it is making loans to finance tank purchases, and a pilot is also underway in Rwanda. In the relatively favorable environment we studied, the lender fully recovered all its principal and interest. Any lender seeking to explore whether these loans would have a high repayment rate more broadly and whether it would be possible to cover administrative costs as well would bear the downside risk but would not fully appropriate the social benefits of learning whether this type of contract generates high repayment more generally. The market will therefore undersupply this experimentation, and there may be a strong case for public subsidies for experiments designed to yield public information on the potential for such lending.

In particular, while the administrative costs of running this particular program likely render it slightly unprofitable, we estimate that the lender could easily cover the administrative cost of the program if it charged farmers a price halfway between the wholesale and retail price of the tanks. We estimate that administrative costs were approximately $15 per farmer, and since the wholesale price is approximately $50 less than the retail price, this would leave a comfortable margin. It might be worth exploring whether this type of program could be financially sustainable, and also worth checking whether a similar approach could be used beyond the dairy sector.

Slightly 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.

While definitive conclusion will have to await further work, it is worth noting that prospect theoretic preferences could account for low loan take up under the SACCO contract, high loan take up when collateralization with the purchased asset is possible, and high repayment rates.

Prospect theoretic agents will be more likely to take up loans when they can use assets purchased with the loan as collateral, because this limits the risk to existing assets. However, that once the tank is purchased, their reference point may shift, creating a strong incentive to retain possession. The possibility of reference-dependent preferences raises important issues for welfare analysis, and at least raises the possibility that allowing loans to be collateralized with the purchased good might “trick" naive agents into taking out loans that they later regret. This suggests that policymakers may want to think about whether they want to subsidize asset-collateralized lending in general or tailor programs in ways that reduce this possibility.

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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)
25% deposit or guarantor	0/718	0	0/718	0
		(0, 0.42)		(0, 0.42)

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.

Table 6: Late repayment

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

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

Table 7: Early repayment

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

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

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

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

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

Table 9: Milk sales

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

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

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

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

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

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

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

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

Note: Enrollment variable equals one if the child is enrolled in school.
Panel observations only, so observations are excluded if the child was younger than five at baseline. Aging of the sample thus likely accounts for downward trend in enrollment captured by the coefficient on Post.
Standard errors clustered at the household level.
* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

Figure 1: Contractual Repayment Periods for Experimental Loans

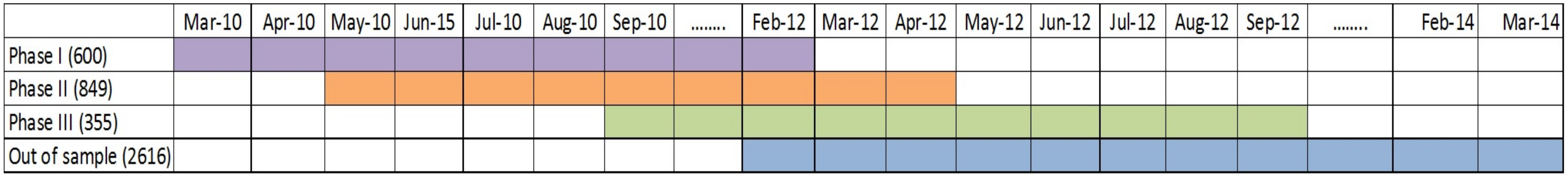

Figure 2: Repayments