Parametric insurance and technology adoption in developing countries

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Abstract

Technology adoption is crucial for the development of low income countries. This paper investigates how parametric insurance can contribute to improve access to technology for smallholder farmers. In a model with moral hazard, we show that bundling a parametric insurance with a loan may lower the collateral required by the lender, hence improving access to credit for poor households. The importance of the wealth constraint on the access to credit is illustrated by data from a survey made among Tanzanian small-holders. Preliminary results seem to provide support to a project currently underway in Tanzania, in order to develop weather-index insurance to banks that grant loans to farmers.

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1 Introduction

The move towards more efficient technologies has undoubtedly played a major role in the long-run economic evolution of most developed countries. In particular, in the field of agriculture, the adoption of hybrid high-yield seeds during the second part of the twentieth century, the construction of reliable irrigation systems and the use of fertilisers and pesticides has fostered considerable productivity gains in many western and Asian countries.

In order to achieve better food security throughout the world, international institutions, such as the World Bank and the Food and Agricultural Organization (FAO), as well as private donors have promoted the adoption of agricultural technologies designed to improve productivity in a process that is known as the green revolution. Despite certain limits (Freebairn (1995); Pingali (2012)), the promotion and diffusion of better technologies that lies at the heart of this green revolution can certainly contribute to improve the living conditions of the many and in particular of the poorer and of those most exposed to food security risks (Parente & Prescott (1994); Evenson & Gollin (2003)). Yet to this day, many sub-Saharan African countries have not benefited from such productivity increase.

The adoption of existing technologies indeed, has proven to be a real challenge despite the expected gains for the farmers themselves (Duflo et al. (2008); Suri (2011)). This challenge has lead academics and practitioners alike to investigate the potential barriers to technology adoption. Among other barriers, behavioural bias have been investigated in Duflo et al. (2011), information spillovers in Foster & Rosenzweig (1995), Bandiera & Rasul (2006), and credit constraints in Karlan et al. (2014).

In an empirical investigation lead in Ethiopia, Dercon & Christiaensen (2011) find that the prospect of very low returns in case of unfavourable climatic events as well as credit constraints were most likely to explain low rates of technology adoption. Based on this idea, inter-linked credit and insurance products have been developed to facilitate technology adoption. Following the failure to scale-up indemnity insurance due to high servicing costs and important moral hazard problems, new hybrid products have been developed with a parametric insurance component. Each product has its specifics but most provide an insurance against default risk for the lenders and some form of insurance against climate risk for the small-holders. Several experiments have taken place over the years and (Carter et al. (2014)), McIntosh et al. (2013), Cole et al. (2017) as well as Hill et al. (2019) find a positive effect of insurance on technology adoption. In contrast, Giné & Yang (2009) find a negative effect.

These mixed empirical results call for additional theoretical clarifications of the underlying effects and for a thorough understanding of the contractual details of each product in order to assess their potential to unlock technology adoption from theoretical and applied perspectives.

In this regard, this paper provides a model focused on the role of parametric insurance when moral hazard, under several forms, limits the access of small-holders to the credit market. We also confront its assumptions and conclusions to data drawn from a survey among small-holder farmers in Tanzania, in order to assess the determinants of credit denials, and the potential gains that can be expected from a weather-index parametric insurance product

In order to address the question of whether parametric insurance may increase technology adoption among small-holders we study how bundling a parametric insurance contract with a loan may lower the collateral required to access credit. We find that this inter-linkage reduces the required collateral whenever the index that triggers the indemnity payment is sufficiently correlated with the actual losses of small-holder farmers.

2 The model

We model a lender-farmer relationship with two different versions of the same basic model, that differ depending on the type of moral hazard. The effect of information asymmetry on credit rationing has been highlighted by several authors following the seminal papers of Jaffee & Russell (1976) and Stiglitz & Weiss (1981). Our own analysis is connected with the approach of Holmstrom & Tirole (1997) who consider a moral hazard setting and emphasise the role of the net worth on credit rationing. Our main focus will be to focus attention on the role of parametric insurance in the analysis of credit rationing. Under *ex-ante* moral hazard, the credit aims at financing technology adoption, but what the farmer actually does with the funds allocated remains his private information. He may therefore decide to consume the credit (or use it in some unproductive way). This lowers the probability of success and therefore, of reimbursing the loan. To meet this default risk, the lender requires a collateral that incentivizes the farmer to effectively adopt the technology.

Under *ex-post* moral hazard, the farmer may strategically default (in which case he falsely claims that his production failed and that he cannot reimburse the loan), while side-selling his production in parallel markets. Since verifying the farmer's output may be prohibitively costly, the lender may prefer to raise a collateral that guarantees the repayment of the loan.

Whatever the type of moral hazard, the model has a common basic structure, with two periods 0 and 1, risk-neutral agents, including a population of farmers, and for notational simplicity, a zero risk-free interest rate. At period 0, each farmer has a technology adoption project that requires a capital I and yields an income R with a probability $1-p$ and 0 with a probability p. Hence $1-p$ is the probability of success of the project. Farmers have no cash available to finance the new technology, and thus each of them requires a loan I. At period 1, farmers must return the principal I and the interest Ir, where r is the rate required by the lender (also called the bank). At period 0, each farmer owns an illiquid asset A that can be used as a collateral but is not meant to finance the project. In order to mitigate the prospect of a default, the bank requires in periods 0 a collateral C, that is returned to the farmer in periods 1 if the loan is repaid. If the farmer faces a loss, he goes bankrupt and defaults, in which case the lender keeps the collateral C. Both farmers and lenders are risk neutral.

The model will allow to compare a traditional loan contract to a contract that bundles a loan with a parametric insurance against climate risk. Indemnity insurance contracts are assumed not to be available due to high verification costs.

2.1 Ex-ante moral hazard

This section presents the case of ex-ante moral hazard, in which the probability p depends on the farmer's behavior, and will be denoted $p(e)$ where e reflects the farmer's behavior. This behavior corresponds to what he does with the funds allocated by the bank, and remains his private information.

In the absence of insurance, and after funds I have been allocated, the farmer's cash-flow at period 1 is 0 with probability $p(e)$, and R with probability $1 - p(e)$, where $e \in \{b, g\}$, with $p(g) < p(g)$. In words, $e = g$ corresponds to a "good" behavior where the farmer actually invests I at period 0 as he is supposed to do in order to improve its production technology, allowing for a lower probability of loss. On the contrary, $e = b$ corresponds to a "bad" behavior, where the farmer uses the loan I for other purposes from which he derives some private benefits (consumption or other unproductive use). The probability distribution of the income $\tilde{R}$ therefore depends on the behaviour of the farmer, in addition to the possible realisation of an exogenous risk factor such as a weather related catastrophe. This risk factor is common to all farmers and its occurrence corresponds to a random variable $\tilde{y} \in \{0, 1\}$, with $\mathbb{P}(\tilde{y} = 1) = q \in (0, 1)$. In what follows, $\tilde{y}$ corresponds to adverse or favorable conditions, such as bad or good weather, respectively, that negatively or positively affect the farmers' probability of success, whatever their behavior. This joint effect of the farmer's behavior $e \in \{b, g\}$, and of the common risk factor $\tilde{y} \in \{0, 1\}$ is modelled by writing the conditional probability of default as

$$
\begin{aligned}
\mathbb{P}(\tilde{R} &= 0|\tilde{y} = 1, e) = f(e) + \varepsilon \\
\mathbb{P}(\tilde{R} &= 0|\tilde{y} = 0, e) = f(e),
\end{aligned}
$$

where $\varepsilon > 0$, $0 < f(g) < f(b)$ and $f(b) + \varepsilon < 1$. In words, for a given behavior $e \in \{b, g\}$, the occurrence of the risk factor $\tilde{y} = 1$ increases the probability of default by an amount ε, while, for a given risk factor $\tilde{y} \in \{0, 1\}$, a bad behavior induces an increase $f(b) - f(g)$ in the probability of default.

We denote $f(g) \equiv f_g$ and $f(b) = f_b$, with $f_b > f_b$. The joint and marginal probability distribution of $\tilde{R}$ and y are given in Table 1 when $e = g$, with a similar table for $e = b$ obtained by replacing f_g by f_b.

$\tilde{R}$ \ $\tilde{y}$	0	1	
R	$(1-q)(1-f_g)$	$q(1-f_g-\varepsilon)$	$1-f_g-q\varepsilon$
0	$(1-q)f_g$	$q(f_g+\varepsilon)$	$f_g+q\varepsilon$
	$1-q$	q	1

Table 1: Joint distribution of the loss and index random variables

Finally, we call $p_g = f_g + q\varepsilon$ and $p_b = f_b + q\varepsilon$ the probability that a loss occurs when the agent invests the capital I and when he does not, respectively.

Case with no insurance

Without insurance, the only possibility for the bank to reduce the risk of loan non-repayment is to require a collateral C, in addition to the interest rate r. We assume

$$(1 - p_g)R - I > (1 - p_b)R,$$

which means that investing I in the project is efficient in terms of expected cash-flow. Equivalently

$$\frac{I}{R} < p_b - p_g. \tag{1}$$

When he takes action e, the expected cash-flow of the farmer in periods 1 is

$$\Pi_1^N(e) = [R - I(1+r)](1 - f(e) - q\varepsilon) - C[f(e) + q\varepsilon],$$

where N refers to the no-insurance case. In this ex ante moral hazard setting, the incentive constraint without insurance is written as

$$\Pi_1^N(g) \geq \Pi_1^N(b),$$

or, equivalently,

$$C \geq \frac{I}{p_b - p_g} - R + I(1+r). \tag{2}$$

The lender receives $I(1+r)$ in periods 1 if $\tilde{R} = R$ and C if $\tilde{R} = 0$. Hence, when the farmer chooses $e = g$, and assuming that the lender requires a profit margin $\eta \geq 0$, his participation constraint is written as

$$(1 - p_g)(1+r)I + p_g C \geq I + \eta,$$

or equivalently,

$$1 + r \geq \frac{\eta + I - p_g C}{I(1 - p_g)}. \tag{3}$$

Combining (2) and (3) gives the smallest collateral required by a lender to grant a loan:

$$C_1^N = I\frac{1 + p_b - 2p_g}{p_b - p_g} - R(1 - p_g) + \eta.$$

In particular, we have $C_1^N > 0$ if

$$\frac{I(1 - p_b - 2p_g)}{(p_b - p_g)(1 - p_g)} > R - \frac{\eta}{1 - p_g},$$

which is compatible with (1). There are therefore some projects with positive expected net present value, for which borrowers with low levels of asset are not able to find financing.

With parametric insurance

We now consider the case of a parametric insurance. Such insurance provides an indemnity to the lender when $\tilde{y} = 1$. Parametric insurance remains imperfect in the sense that, with a probability $q(1 - f(e) - \varepsilon)$, it fails to perform while the farmer makes default. Conversely, with probability $(1 - q)f(e)$, the insurance delivers an indemnity while no loss occurs. The case $\varepsilon = 1$ and $f = 0$ represents a perfect index, where there is an insurance payout if and only if the farmer defaults.

We assume that parametric insurance pays $(1+r)I$ to the lender when $\tilde{y} = 1$, in which case it exempts the farmer from its obligation to repay the loan. It does not pay anything when $\tilde{y} = 0$. The loan contract stipulates that the farmer receives his collateral back when the loan is repaid, either by the farmer when $\widetilde{R} = R$ and $\widetilde{y} = 0$ or by the insurer when $\widetilde{y} = 1$ (and $\widetilde{R} = 0$ or R). The contract between the lender and the farmer stipulates these clauses, which means that the loan and the insurance contract are bundled. Finally, the insurance premium P is paid by the lender directly to the insurance provider at an actuarial price. Since $\widetilde{y} = 1$ with probability q, we have $P = q(1 + r)I$.

In short, the lender purchases an insurance that pays $I(1 + r)$ when $\tilde{y} = 1$ in which case the farmer is exempted from loan repayment, and whose price is passed on to the farmers through the interest rate. Since the collateral is returned to the farmer in case of default if $\widetilde{y} = 1$, his period 1 expected cash-flow under behavior e is

$$\Pi_1^I(e) = (1 - q)[1 - f(e)][R - I(1 + r)] + q[1 - f(e) - \varepsilon]R - (1 - q)f(e)C,$$

where I refers to insurance, and his incentive constraint

$$\Pi_1^I(g) \geq \Pi_1^I(b)$$

yields

$$C \geq \frac{I}{(1 - q)(p_b - p_g)} - \frac{R}{1 - q} + I(1 + r). \tag{4}$$

Conditional on the incentive constraint being satisfied, and deducing the insurance premium, the cash-flow of the lender is written as

$$I(1 + r)[1 - (1 - q)f_g] + C(1 - q)f_g - I - qI(1 + r), \tag{5}$$

since the only case where the lender does not receive the loan repayment is when $\tilde{R} = 0$ and $\tilde{y} = 0$. Assuming a monopolistic income $\eta \geq 0$ gives the participation constraint

$$I(1 + r)[1 - (1 - q)f_g] + C(1 - q)f_g \geq I + qI(1 + r) + \eta. \tag{6}$$

Using (4) and (6) gives the lowest possible collateral

$$C_1^I = \frac{1}{1 - q}[I\frac{1 + f_b - 2f_g}{(1 - q)(f_b - f_g)} - R(1 - f_g) + \eta].$$

C_1^I is a function of q, with $C_1^I = C_1^N$ when $q = 0$, which indeed coincides with the no insurance case. In addition, we have $C_1^I < C_1^N$ if $\varepsilon \geq \varepsilon_1$, where

$$\varepsilon_1 = \frac{[I\frac{1+f_b-2f_g}{(1-q)(f_b-f_g)} - R(1-f_g) + \eta]/(1-q)}{R - I/(f_b - f_g)} \tag{7}$$

$$= \frac{(1-q)C^P}{R - I/(f_b - f_g)} \tag{8}$$

ε is a measure of the informativeness of the parametric cover, since it corresponds to the increase in the probability of default when $\widetilde{y}$ changes from 0 to 1, and ε_1 is the lower bound of this informativeness parameter over which parametric insurance leads to a decrease in the required collateral. The larger the profitability of the project, the lower the informational requirement on the parametric index. When this condition is satisfied and assuming that wealth A is distributed among farmers with c.d.f. F, we deduce that using parametric insurance allows to increase the number of farmers who access the credit market by a proportion $F(C_1^N) - F(C_1^I)$.

The bundled parametric insurance provides an improvement in the condition of access to credit because the index allows to disentangle (imperfectly) the case in which the farmer strategically defaults from the case where he suffers an exogenous shock. This separation helps to maintain the incentive power of the collateral despite the (partial) insurance granted to the farmer.

Compared to the case without insurance, the parametric insurance therefore leaves unchanged the incentive constraint for a given rate of return. However, it has two opposite effects on the interest rate. On the one hand, the cost of insurance puts an additional financial burden on the lender, who passes it on to farmers through the interest rate. The increase in the interest rate in turn makes it more profitable for the farmer to strategically default, hence contributing to an increase in the required collateral. On the other hand, the insurance provides a hedge against the states where the farmer defaults, hence contributing to lower the required interest rate r and the required amount of collateral. Which of these two effects dominates depends on the quality of the index, as measured by ε. If the index is a sufficiently powerful signal of a loss, it allows for an overall reduction in the collateral. In contrast, a poor design may worsen the conditions of access to credit and impede technology adoption for poorer farmers.

2.2 Ex-post moral hazard

No insurance

In this section, the farmer always invests the loan in the technology improvement project. However, the outcome of the project is known by the farmer only, who may therefore decide to report a low income and go bankrupt to avoid reimbursing. When he does so, he incurs a cost B, that may reflect the risk of being caught, the risk of being unable to obtain further financing or simply a moral or social cost. We assume that there is no ex ante moral hazard (behavior

$e = g$ without any particular condition, because the lender can check at no cost that the project has been implemented), and we more simply denote $f(g) = f$.

The cash-flow stream faced by the farmer is summarised in Table 2.

No strategic default: period 0	No strategic default: period 1		Strategic default: period 0	Strategic default: period 1	
$I - C$	$R - I(1+r) + C$	$(1-p)$	$I - C$	$R - B$	$(1-p)$
	0	p		0	p

Table 2: Farmer's cash-flows.

The farmer has no incentive to strategically default if the incentive constraint

$$C \geq I(1+r) - B \tag{9}$$

is satisfied. Under this condition, the expected cash-flow of the lender is

$$\Pi_2^N = (1-p)I(1+r) + pC - I,$$

and assuming a monopolistic income η he enters the market if the participation constraint

$$r \geq \frac{(I-C)p + \eta}{I(1-p)} \tag{10}$$

is satisfied. Taking the equality of (9) and (10) gives the smallest collateral available on the market

$$C_2^N = I + \eta - B(1-p), \tag{11}$$

and the lowest interest rate

$$r^N = \frac{B+\eta}{I}.$$

Parametric insurance

As previously, let $\tilde{R}$ be the random income associated with the project. We assume

$$\begin{aligned} \mathbb{P}(\tilde{R} &= 0|\tilde{y} = 1) = f + \varepsilon \\ \mathbb{P}(\tilde{R} &= 0|\tilde{y} = 0) = f, \end{aligned}$$

with $\varepsilon > 0$ and $f + \varepsilon < 1$. The joint p.d.f. of $\tilde{R}$ and $\tilde{y}$, as well as the marginal distributions are also given in Table 1. The cash-flows of the farmer can therefore be written as in Table

The incentive constraint writes as previously

$$C \geq I(1+r) - B. \tag{12}$$

	No strategic default		Strategic default
period 0	period 1	period 0	period 1
$I-C$	$R-I(1+r)+C$	$I-C$	$R-B$ $(\tilde{R}=R,\, \tilde{y}=0)$
	$R+C$		$R+C$ $(\tilde{R}=R,\, \tilde{y}=1)$
	0		0 $(\tilde{R}=0,\, \tilde{y}=0)$
	C		C $(\tilde{R}=0,\, \tilde{y}=1)$

Table 3: Farmer's cash-flows with parametric insurance.

If the incentive constraint is satisfied, the cash-flow of the lender in period 1 is $I(1+r)-P$ when there is no loss, which occurs with probability $1-f-q\varepsilon$. When the index is 1, the lender receives full indemnity $I(1+r)$ from the insurer, whether the farmer actually suffers a loss or not. He consequently has a payoff $I(1+r)-P$ with a probability $1-(1-q)f$. With probability $(1-q)f$, there is a loss but the insurance does not pay. In this case, the lender keeps the collateral C and his period 1 cash-flow is $C-P$.

Assuming actuarially fair coverage $P=qI(1+r)$ and a level of profit $\eta \geq 0$, the lender therefore participates if

$$[1-(1-q)f]I(1+r)+(1-q)fC \geq I+qI(1+r)+\eta,$$

If the incentive constraint holds with equality, the lowest collateral required by the lender is

$$C_2^I = \frac{I+\eta+B(1-q)(1-f)}{1-q}. \tag{13}$$

Comparing (13) with (11) shows that the collateral with a parametric insurance is lower than the collateral without insurance if

$$\varepsilon \geq \frac{I+\eta}{(1-q)B},$$

that is, if the signal $\tilde{y}$ is sufficiently informative about the likelihood of a loss. In this case, the introduction of the parametric insurance program therefore allows more farmers to access credit. More precisely, if A is distributed across the population of farmers with c.d.f. F, then the proportion of farmers who access credit thanks to the insurance scheme is

$$F(C_2^N)-F(C_2^I).$$

3 Some empirical results

This section illustrates our theoretical results on the link between wealth and access to credit by using data from a survey made among smallholder farmers in Tanzania. The background of this survey is the impulse toward the adoption of more productive technologies given by the World Food Program within the

Farm to Market Alliance (FtMA), as well as the development of weather-index insurance for banks granting loans to farmers, currently underway in Tanzania.

Essentially, all rural households in Tanzania participate in agriculture, earning from it an average of 70% of their income.[1] However, cereal yields and agricultural labor productivity have failed to experience significant increases in that country during the last decades[2] largely due to low staple crop productivity, which has been linked to poor agronomic practices and limited use of modern farming techniques, as well as financial constraints such as limited access to savings, credit and insurance. Addressing individual inefficiencies has rarely resulted in material productivity boosts (see the limited success of Smart Input Subsidy Programs[3]), whereas integrated approaches seem to be more promising. Against this background, in 2015 the World Food Programme (WFP) promoted the Farm to Market Alliance (FtMA) initiative to support the sustainable growth of smallholder farms in several African countries, including Tanzania (Vandercasteelen & Christiaensen (2018)). The Alliance is a demand-driven consortium of public and private value chain stakeholders aiming to facilitate smallholder farmers' participation across entire value chains in order to raise their marketable surplus production and therefore livelihoods. In Tanzania, the Alliance decided to focus on maize production by targeting an initial pool of 75,000 smallholders during the period 2016-18. The objective was to improve the supply chain for commercial maize markets by linking Farmers Organizations (FOs) to domestic buyers (through guaranteed market access at a minimum price), as well as financial institutions (for credit), input providers and extension service providers (facilitated through different NGO's). Incentivizing farmers to adopt more productive technologies (draught-tolerant seed varieties, better quality fertilisers, more efficient use of inputs with reduction of acidification,...) is the main objective of promoting access to credit.

The extension of credit was facilitated by the bundling of a parametric insurance product[4] with loan agreements so as to help farmers service their loans in the face of adverse weather events. The first round of the Tanzanian FtMA intervention was deployed during the production year 2015-2016 and covered 21,000 farmers across 29 FOs. It was implemented in three zones and nine regions across the three main maize areas of Tanzania: a) Kilimanjaro, Manyara, Arusha in North Tanzania (6,000 farmers); b) Morogoro, Singida, Dodoma in Central Tanzania (8,000 farmers); c) Njombe, Ruvuma, and Iringa in South Tanzania (7,000 farmers). These nine regions represent Tanzania's key maize

[1] In Tanzania, income from crops is dominant, followed at a distance by livestock and agricultural wage labor (Davis et al. (2014))

[2] They are still at 1464 kg/ha and 563 US $ per worker levels, respectively, when averaged over 2012-14 (World Bank (2016)).

[3] Starting with Malawi‘s lead in the mid-2000s, there has been renewed interest in input subsidy programs across Africa, but it has become soon apparent they have not delivered the desired results while at the same time proving to be unsustainable from a fiscal point of view; see Morris et al. (2007) and Jayne & Rashid (2013), for example.

[4] The insurance product was deployed by Jubilee Insurance of Tanzania with the support of Munich Re, researchers at the Brevan Howard Centre for Financial Analysis at Imperial College London, and Climate-KIC.

producing areas. In the production season 2016-2017, WFP expanded the scope of FtMA to reach a total target of 50,000 farmers including the 21,000 farmers who already received the FtMA intervention in the previous year and 29,000 new farmers deemed to be eligible to receive the intervention, for a total of 50,000 farmers. The FtMA intervention provided farmers with a full set of agricultural services ranging from input credit to tailor-made input packages, forward delivery contracts, agricultural practice training, postharvest training, aggregation centers, drying and post-harvest equipment. The baseline survey was designed in line with the larger roll out of the FtMA intervention in which also bundled insurance was included for part of the FOs.

Baseline survey data

The baseline survey[5] was developed in two phases. Data was first collected after harvest from the maize season $2015-2016$, in order to understand input and output decisions before the FtMA intervention was rolled out. However, as right after harvest is when farmers have access to most of the crop and sales income, a second component of the survey was run before harvest in 2018, in order to better understand food security and consumption. For the baseline survey, a total of 1,933 farmers were interviewed across 108 FOs spread across the country.

The access to credit is captures by the survey question "Over the past 12 months, did you or anyone else in this household borrow from someone outside the household OR did you or anyone else in this household receive any cash/goods/services from an institution on credit?".

Data also include information about whether the farmers have a bank account or not, through the the question " Do you or anyone else in your household have a bank account, either with a commercial bank , a credit union, or other similar institution?" and split the sample into the following four groups:

i. (No loan, no need): households that did not take up loan, and indicate that the reason is no need for a loan;

ii. (No loan, other): households that did not take up a loan for other reasons than "no need";

iii. (Loan, no bank account): household that took up a loan, but have no bank account;

iv. (Loan, bank account): households that took up a loan and have a bank account.

The distribution of agricultural asset values across the four groups above is depicted in Figure 1. The distribution of agricultural asset value and farm size in the sample clearly illustrates that these are smallholders with very low

[5]The survey was financed by the Let's Work Tanzania Programme of the World Bank and the Climate-KIC funded WINnERS project led by Imperial College London.

productive assets. We focus attention on the reason for which such farmers may not be granted loans. Is it because they do not apply for a loan, either because the interest would be too high, or because they would consider borrowing as a too risky decision, or because they think they do not need such a loan ? Or, is it because they are refused access to credit, and in such a case, what are the key drivers of credit denial?

Asset values are expressed as the logarithm of Tanzanian shillings (in thousands). The distribution of farm size (measured in hectares) across the four groups is depicted in Figure 2.

The results of a regression analysis of the answers to the survey questions are reported in Table 3. The results indicate a strong negative relationship between having to access a loan and farm size. This supports the idea that low collateral values/availability forces farmers to use informal forms of credit, without having access to the banking system.

Table 4 reports the regression results obtained by adding several controls. In line with the empirical predictions of the models of section 2, we find that the availability of the size of the firm, that proxies for the amount of collateral available is negatively related with credit access. Moreover, farm size is strongly negatively related to both being rejected and expecting to be rejected by a loan provider. In fact, farm size seems to be an important determinant in most tested specifications.

[**Empirical work to be completed**]

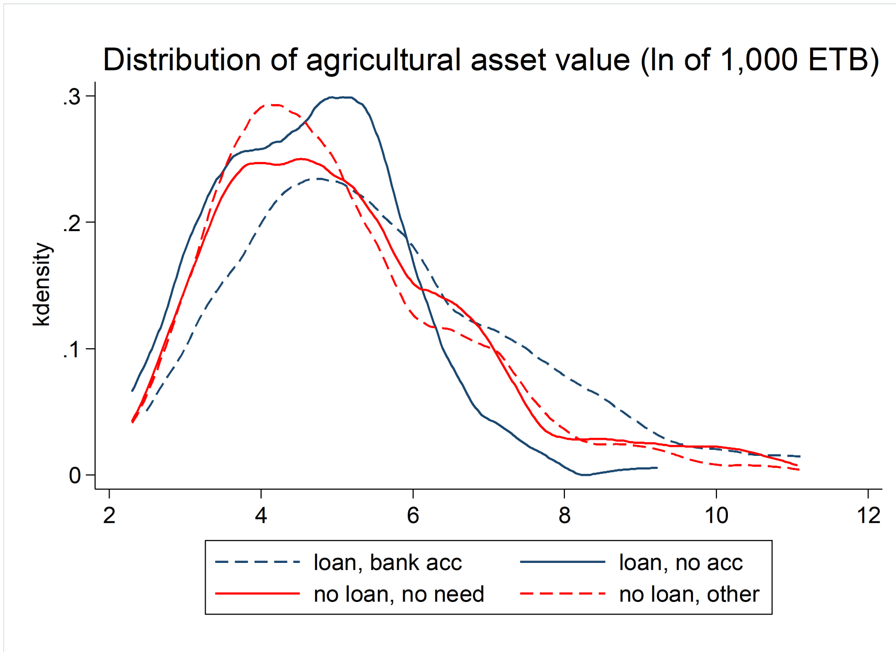
Distribution of agricultural asset value (ln of 1,000 ETB)
kdensity
.3
.2
.1
0
2
4
6
8
10
12
loan, bank acc
loan, no acc
no loan, no need
no loan, other

Figure 1

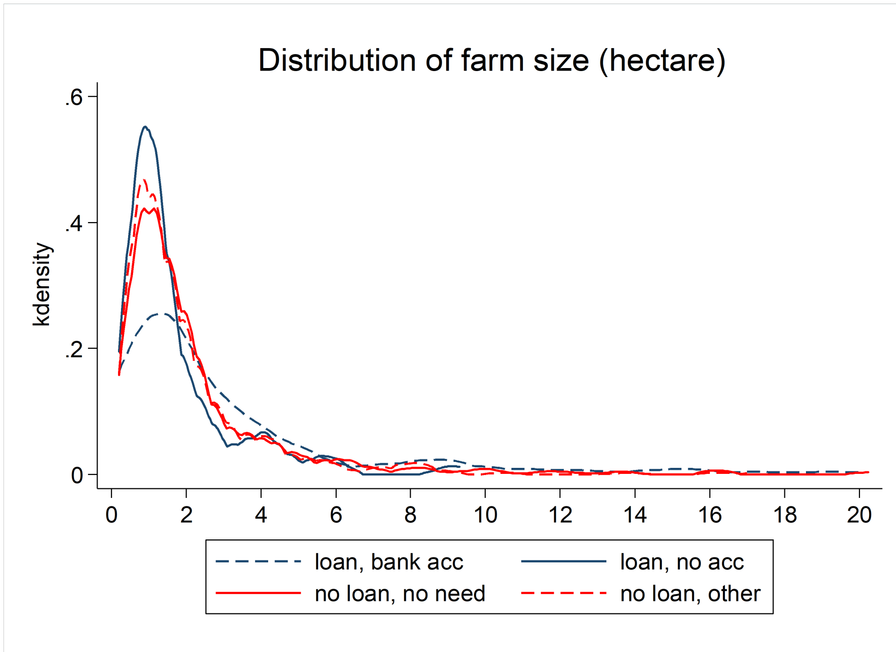
Distribution of farm size (hectare)
kdensity
.6
.4
.2
0
0
2
4
6
8
10
12
14
16
18
20
loan, bank acc
loan, no acc
no loan, no need
no loan, other

Figure 2

Analysis of reasons for not taking out loan

VARIABLES	No need for a loan	Tried, but was refused	No-one available to give loans	Expected to be rejected	No assets for collateral	No land titles for collateral	Afraid of losing collateral	Afraid cannot pay back	Interest rates too high	Bank/MFI too far located	Lack of information on loan	Other
Value of agr. assets (million TSH)	0.24	0.06	-0.04	0.04	-0.03**	-0.01	-0.07**	0.25	-0.33**	0.11	-0.22***	0.02
	(0.36)	(0.05)	(0.15)	(0.09)	(0.01)	(0.01)	(0.04)	(0.27)	(0.15)	(0.06)	(0.07)	(0.03)
Farm size (ha)	1.02**	-0.27***	-0.08	-0.31***	-0.22***	0.01	0.04	-0.67**	0.69*	-0.06	-0.16	0.01
	(0.49)	(0.08)	(0.39)	(0.11)	(0.07)	(0.07)	(0.16)	(0.34)	(0.38)	(0.17)	(0.31)	(0.04)
Constant	42.68***	1.55***	11.26***	3.02***	2.12***	0.61**	2.73***	12.18***	11.58***	0.88*	11.19***	0.20*
	(1.51)	(0.38)	(1.24)	(0.52)	(0.38)	(0.27)	(0.57)	(1.16)	(1.05)	(0.47)	(1.14)	(0.12)
Observations	1,604	1,604	1,604	1,604	1,604	1,604	1,604	1,604	1,604	1,604	1,604	1,604
R-squared	0.003	0.003	0.000	0.002	0.002	0.000	0.000	0.003	0.003	0.003	0.002	0.000

Robust standard errors in parentheses

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

Figure 3

VARIABLES	No need for a loan	Tried, but was refused	No-one available to give loans	Expected to be rejected	No assets for collateral	No land titles for collateral	Afraid of losing collateral	cannot pay back	rates too high	too far located	information on loan	Other
Value of agr. assets (million TSH)	0.17	0.03	-0.02	0.06	-0.02*	-0.01	-0.05	0.31	-0.34**	0.07	-0.21**	0.02
	(0.38)	(0.02)	(0.17)	(0.10)	(0.01)	(0.01)	(0.04)	(0.28)	(0.16)	(0.05)	(0.08)	(0.03)
Farm size (ha)	1.00*	-0.20***	-0.11	-0.32***	-0.22***	-0.00	0.04	-0.73**	0.58	0.04	-0.07	0.01
	(0.54)	(0.06)	(0.39)	(0.11)	(0.07)	(0.07)	(0.16)	(0.33)	(0.39)	(0.17)	(0.33)	(0.05)
head_age	-0.10	-0.00	-0.01	0.03	-0.02	0.00	0.02	0.15**	-0.03	-0.01	-0.03	0.00
	(0.10)	(0.01)	(0.06)	(0.03)	(0.03)	(0.02)	(0.03)	(0.06)	(0.07)	(0.02)	(0.06)	(0.01)
head_school_level	0.84***	0.01	-0.33***	-0.09***	0.07	-0.01	-0.16***	-0.31**	0.18	-0.03**	-0.18	-0.01
	(0.27)	(0.03)	(0.11)	(0.03)	(0.08)	(0.02)	(0.05)	(0.14)	(0.21)	(0.01)	(0.13)	(0.01)
head_male	-4.44	-0.16	-1.21	0.73	0.12	-0.49	0.49	0.45	2.78	0.71**	0.73	0.29*
	(3.62)	(0.75)	(2.42)	(0.94)	(0.96)	(0.70)	(1.07)	(2.27)	(2.57)	(0.28)	(2.48)	(0.15)
head_bornincomm	8.84	0.92***	-4.19	-0.43	1.82***	0.67**	-2.66	-5.66	1.19	0.50***	-1.26	0.25*
	(5.66)	(0.28)	(4.16)	(1.55)	(0.43)	(0.27)	(2.08)	(3.92)	(4.19)	(0.19)	(3.16)	(0.13)
Constant	29.24***	0.42	22.65***	2.70	-0.06	0.43	6.33**	14.65**	7.11	0.60	16.31***	-0.37
	(8.73)	(1.14)	(6.00)	(2.33)	(2.41)	(1.09)	(2.55)	(6.35)	(6.52)	(0.93)	(5.19)	(0.71)
Observations	1,482	1,482	1,482	1,482	1,482	1,482	1,482	1,482	1,482	1,482	1,482	1,482
R-squared	0.012	0.003	0.004	0.004	0.004	0.001	0.005	0.012	0.005	0.004	0.002	0.001

Robust standard errors in parentheses

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

Figure 4

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