The Impact of Access to Credit on the Adoption of hybrid maize in Malawi: An Empirical test of an Agricultural Household Model under credit market failure

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Abstract

A substantial amount of the literature has reported on the impact of access to credit on technology adoption, and many studies find that credit has a positive impact on adoption. However, most existing studies have failed to explicitly measure and analyze the amount of credit that farm households are able to borrow and whether they are credit constrained or not. They overlooked the fact that credit access can be a panacea for non-adoption only if it is targeted at households that face binding liquidity constraints. Guided by the frame work of a household model under credit market failure, this paper aims at investigating the impact of access to credit on the adoption of hybrid maize among households that vary in their credit constraints. The data used in the study is from Malawi collected by the International Food Policy Research Institute (IFPRI).Using the direct elicitation approach, households are classified into constrained and unconstrained regimes. We start by estimating the probability of being credit constrained, followed by an estimation of the impact of access to credit for the two categories of households (credit constrained and unconstrained), while accounting for selection bias. The impact of access to credit is estimated using a switching regression in a Double-Hurdle model. Results reveal that while access to credit increases adoption among credit constrained households, it has no effect among unconstrained households. Results also show that factors that affect adoption among credit constrained households are different from those that that affect adoption among unconstrained household. Landholding size, for example, has opposite effects on adoption in the two regimes of households. The policy implication is that microfinance institutions should consider scaling up their credit services to ensure that more households benefit from it, and in so doing maize adoption will be enhanced.

Keywords: Credit constraints, Double-hurdle, hybrid maize, adoption, Malawi

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1.0 Introduction

Food security in Malawi is mainly defined in relation to the availability of maize, the main staple in the country. It is for this reason that the Malawi's agricultural policy for the past two decades, emphasized the production of hybrid maize, a capital intensive and high yielding technology as a substitute to the local maize varieties. Efforts to diversify away from maize into other food crops have failed largely because maize being a C4 plant produces more calories per unit of land area than all other food crops grown in Malawi. It is therefore, likely that Malawi will continue to rely on maize as a major food crop. In addition the policy emphasis has been on tobacco, a labor and capital intensive cash crop. A combination of the two crops continues to be seen as a potential option for improving the income and food security of rural households in Malawi (Zeller *et al*., 1998).

The provision of micro-credit to farmers is widely perceived as an effective strategy for promoting the adoption of improved technologies. It is believed that access to credit promotes the adoption of risky technologies through the relaxation of the liquidity constraint as well as through the boosting of household's-risk bearing ability. With an option of borrowing, a household can do away with risk reducing but inefficient income diversification strategies and concentrate on more risky but efficient investments (Eswaran and Kotwal, 1990).

Recognizing the potential contribution of credit in enhancing the adoption of hybrid maize among smallholders, the government of Malawi has been pursuing a credit policy that seeks to promote hybrid maize production. The government of Malawi, through the Smallholder Agricultural Credit Administration (SACA), started providing joint liability loans to smallholder farmers as far back as 1973, three years before the Grameen Bank was created (Diagne, *et al.,* 2000). The credit whose main purpose was to promote smallholders' production of high value crops (first maize, then later in the 1990s also tobacco) was mainly given to farmers in the form of in-kind loans such as fertilizer and seed. However, despite such concerted efforts by the government, and more recently non-governmental organizations in promoting the cultivation of hybrid maize, its adoption remains low. By 2003, more than half of the total maize land was allocated to local varieties (GOM, 2004).

It is often asserted that in addition to taste preferences an on-farm storage constraints (Smale, 1995), and to risk aversion (Simtowe *et al,* 2006), credit constraints are widely responsible for the low adoption of hybrid maize due to its requirements for costly inputs.

A substantial amount of adoption literature has reported on the impact of access to credit on adoption, and a good deal of it showing that credit has a positive impact on adoption. For, example, Feder and Umali (1993) and Cornejo and McBrid (2002) review factors that affect technology adoption, and they highlight access to credit as a key determinant of adoption of most agricultural innovations. Nevertheless, most studies that have looked at the impact of credit have generalized their analysis by assuming that credit access should always lead to positive impact outcomes. Such studies have ignored household behavior with regards to whether or not the household is credit constrained. In reality, however, there are circumstances in which access to credit may have no impact on household welfare. Credit access will only be effective for the credit "constrained" – thus those with access to remunerative consumption, production and investment opportunities who are unable to pursue the opportunities for lack of financial resources. A lack of access to credit may not necessarily imply an unmet credit need (*de* Janvry et al 1997). In the same way, the marginal contribution of credit is likely to be high in households that have a larger binding credit constraint than in those that are less constrained. Considering separability in production decision models is important because the comparative statics for households facing a market failure such as credit constraints are different from those without a market failure, such that models that do not take into account such differences will lead to inconsistent parameter estimates (Vakis *et al.*, 2004). In Malawi, as else where, all credit impact studies have not taken into account the potential inconsistency that may result from such incorrect modeling. Knowledge of whether or not access to credit enables a household to make its production and consumption decisions separably is also crucial as it enables us to capture other potential constraining factors, such as complementary market failures and other factors that might make credit ineffective to beneficiary households.

Building on the economic theory of the agricultural household model under credit market failure, this paper aims at investigating the extent to which access to credit enables smallholder farmers to adopt hybrid maize production in Malawi. The study uses a Double-Hurdle model in estimating the determinants of adoption due to a presumption that factors that influence the household's decision to adopt are different from those that affect the extent of adoption. Using the direct elicitation approach developed by Diagne, Zeller Sharma (200), households are classified into credit constrained and unconstrained regimes. The effect of access to credit on the adoption of hybrid maize is estimated using a switching regression approach by taking into account the selection bias associated with categorizing the sample into constrained and unconstrained regimes. We start by estimating the probability of being credit constrained, followed by an estimation of the impact of access to credit for the two regimes of households (credit constrained and unconstrained), while accounting for selection bias. Data used in this study is from Malawi collected by the International Food Policy Research Institute (IFPRI). The rest of the paper is arranged as follows: in section two we present a review of maize production in Malawi and the role of credit. In section three we present the theoretical framework while the empirical approach used is presented in section four. The data used for the estimation is described in section five. In section six we present and discuss results, while section seven concludes.

2.0 Maize production in Malawi: a review

A significant feature in Malawi´s agriculture is the dominance of maize in the farming systems. It is estimated that more than 70 percent of the arable land is allocated to maize production (Government of Malawi, 2004). It is also noted that despite efforts to diversify away from maize, the land allocated to maize continues to rise. Carr (1997) notes that the continued rise in the land allocated to maize could be attributed to the fact that maize is a C4 plant, such that it produces more calories per unit land area than other crops grown in Malawi. With the decline in farm size, small holders have allocated more of their land to maize. Nevertheless due to the short and single farming season, combined with the lack of inputs that accompany the production of maize, yields of maize remain low leading to food insecurity for more than 60 percent of the households who run out of food 4 months before the next harvest(World bank, 1996). The natural response by the government of Malawi has been the introduction of hybrid maize suited for both the climate and food preferences of farmers. Due to the continuous decline in soil fertility, farmers developed special interest in the use of fertilizer such that by 1995 over 90 percent of the maize was fertilized (CIMMYT, 1995).

As a way of achieving the policy of intensifying maize production through the use of hybrid maize seed and fertilizer, the government embarked on an ambitious credit program based on joint liability lending. Agricultural extension officers were given a task of overseeing the functioning of the credit groups and monitoring loan repayment. Supported by the Malawi Congress Party (MCP), the ruling party at that time, Conroy (1992) notes that this exerted pressure on farmers to repay, enabling Malawi to register the highest repayment rates of 95 percent for a number of years. In his paper "a green revolution frustrated" Carr (1997) notes that the rapid increase in hybrid maize seed and fertilizer use which was encouraged by a sharp rise in the supply of credit to smallholder farmers led a number of observers in the World Bank and CYMMT to refer to developments in Malawi as being a Green Revolution. In her paper "Maize is Life: Malawi's delayed Green revolution", Smale (1995) expected that there would be a continued increase in both the area allocated to hybrid maize as well as the yield. The reality though is that the land allocated to hybrid maize remains low.

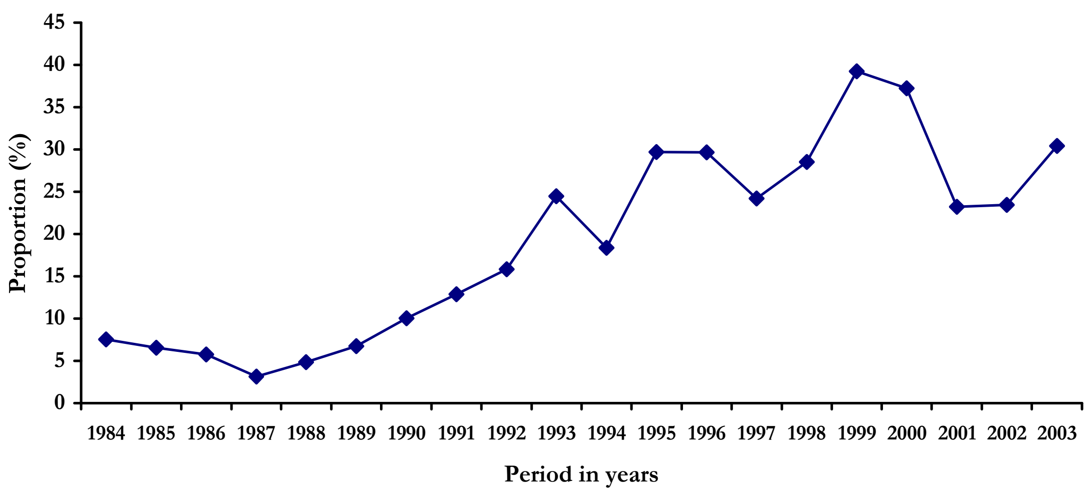

Figure 1: Share of maize land allocated to hybrid maize production

Figure 1 presents the trend in the share of land allocated to hybrid maize from 1984 to 2003. Although there is appositive trend in land allocated to hybrid maize (as shown by the increase from about 8 percent in 1984 to 30 percent in 2003), there has been a number of fluctuations resulting from both policy influences as well as natural disasters such as drought. The steady increase in the share of hybrid maize area was halted in 1994 when it fell to 18 percent due to the collapse of the Small holder Agricultural Credit Administration (SACA).

Zeller et al (1998) note that, while 400,000 farmers received credit in 1992 only 34,000 did so in 1994. This led to an increase in the share of small holder land area planted to non-maize crops such as cassava and pulses. Zeller et al (1998) observe that the response of farmers to the perceived advantages of drought-resistant crops, the sudden collapse of the public system for distributing credit for maize production, and the government policy orientation towards diversifying smallholder crop production may all have played a role in this outcome. Nevertheless, the increasing trend picked up after 1994 due to the large scale distribution of free fertilizer and hybrid maize seed. A sharp fall was experienced in 2001 and 2002 but 2003 saw a recovery to 30 percent of the land allocated to hybrid maize. From the review it is clear that more has to be done if the government policy of expanding the production of hybrid maize to more than half of the total maize land area is to be achieved. A research on the role of credit on adoption of hybrid maize which takes into account the household credit constraint status is pertinent in that it will inform credit policy makers on the type of farmers to target for credit (or on the role of credit in fostering hybrid maize production).

3.0 Theoretical framework

Static household models that stress the role of pervasive risks, limited information, and imperfect markets on household's behavior have been widely used. Singh *et al.* (1986) note that predictions derived from these models differ markedly from those under a standard household model where separability between production and consumption decisions is assumed. Under separability, allocation of resources in production can be decided independently of consumption decisions. However, separability breaks down when there is a market failure such that production and consumption decisions need to be taken jointly. In agricultural production, expenditure and income profiles are markedly seasonal and thus the liquidity constraints in financing production and consumption can be particularly acute (*de* Janvry *et al.,* 1999). This prompts households to adjust their income generating strategies and their expenditure patterns to bring the distance between the two profiles within the range of available credit.

Thus in this study we assume a static household model that links adoption of improved technologies with a growing season liquidity constraint. It is assumed that a household chooses between growing a local maize variety (*lm*) that is not subject to the growing season liquidity constraint and hybrid maize (*hm*) which is subject to the growing season liquidity constraint. The household is assumed to be maximizing the following utility function:

$$\underset{q_{hm},q_{lm},l_{lm}l_{hm},q_{xhm},c_{hm}c_{lm},c_m,c_l}{Max} U(c_{hm},c_{lm},c_m,c_l;z^h) \qquad (1)$$

where:

U is the utility function to be maximized,

c_{hm},c_{lm},c_m and c_l are quantities consumed of hybrid maize, local maize, manufactured good, and leisure, respectively.

z^h is a set of household characteristics that influence consumption

Subject to:

(2)

$$p_{xhm}q_{xhm} + p_m c_m + p_{hm}c_{hm} + p_{lm}c_{lm} = p_{hm}q_{hm} + p_{lm}q_{lm} + w(l_s) + K$$

Seasonal liquidity constraint

$$g(q_{hm},q_{lm},l_{lm},l_{hm},q_{xhm},;z^q) = 0$$

production function

$$l_s + l_{lm} + l_{hm} + c_l = E,$$

time constraint

where:

q_{hm},q_{lm} are quantities of hybrid maize and local maize produced , respectively

l_{lm}, l_{hm} and l_s are quantities of labor used in the production of local maize, hybrid maize, and labor sold out by the household, respectively

q_{xhm} is the quantity of extra inputs required for the production of hybrid maize, such as improved seed, pesticides, etc,

Z^q is a set of fixed factors in production and farm household specific characteristics that influence production,

p_{xhm} and w are input prices for inputs specific to hybrid maize and the wage rate on the labor market, respectively,

p_{hm} and p_{lm} are farm gate prices for hybrid maize and local maize.

p_m is the price for the manufactured good,

E is the total time endowment,

K is the liquidity from past savings, credit, and pre-harvest transfers.

In peasant economies with rare opportunities for off farm income, maximizing the consumption function is closely associated with maximizing farm profits which are then used to finance the consumption decisions. In this case it means maximizing profits from the production of hybrid maize and local maize. The maximization problem above yields the following Lagrangean function:

$$L = U(c_{hm}, c_{lm}, c_m, c_l; z^h) \tag{3}$$

$$+\lambda_1\{p_{hm}q_{hm} + p_{lm}q_{lm} + w(l_s) + K - p_{xhm}q_{xhm} - p_m c_m - p_{hm}c_{hm} - p_{lm}c_{lm}\}$$

$$+\ \lambda_2(g(q_{hm}, q_{lm}, l_{lm}, l_{hm}, q_{xhm},; z^q) +\ \lambda_3(E - l_s - l_{lm} - l_{hm} - c_l)$$

Assuming an interior solution, the maximization problems yields the following first order conditions:

$$\frac{\partial L}{\partial c_{hm}} = U_{hm} - \lambda_1 p_{hm} = 0 \tag{4}$$

$$\frac{\partial L}{\partial c_{lm}} = U_{lm} - \lambda_1 p_{lm} = 0 \tag{5}$$

$$\frac{\partial L}{\partial c_m} = U_m - \lambda_1 p_m = 0 \tag{6}$$

$$\frac{\partial L}{\partial c_l} = U_{cl} - \lambda_3 = 0 \qquad (7)$$

$$\frac{\partial L}{\partial q_{xhm}} = \lambda_2 q_{xhm} - p_{xhm}(1+\lambda_1) = 0\,,\ \lambda_1 \geq 0 \qquad (8)$$

$$\frac{\partial L}{\partial l_{hm}} = \lambda_2 l_{hm} - \lambda_3 = 0 \qquad (9)$$

$$\frac{\partial L}{\partial l_{lm}} = \lambda_2 l_{lm} - \lambda_3 = 0 \qquad (10)$$

λ_1 is a multiplier associated with the credit constraint. The multiplier represents an additional amount of inputs for the production of hybrid maize (q_{xhm}) that a farmer will purchase for each additional unit of cash or credit. This is valid only when the farmer fails to acquire optimum inputs required due to lack of cash. Thus it is only relevant to credit or liquidity constrained households. For unconstrained households the multiplier does not have an effect on their production decision. There are, therefore, two scenarios depending on whether the credit constraint is binding or not. First, we consider a case where there is no binding constraint on the amount which the household can borrow. Thus the credit constraint is not binding and therefore, $\lambda_1 = 0$. Under this scenario, the first order conditions for the optimum input requirements are given as follows:

$$\frac{\partial L}{\partial q_{xhm}} = \lambda_2 q_{xhm} - p_{xhm} = 0 \qquad (11)$$

The optimum quantity of input q_{xhm} is given by:

$$q^u{}_{xhm} = \quad q^u{}_{xhm}(p_{hm}, p_{lm}, p_{xhm}, z^q, E) \qquad (12)$$

The superscript *u* refers to the unconstrained case.

In the second scenario we have a household that can not borrow as much as it wants. The household is said to face a credit constraint $(\lambda_1 > 0)$. The first order Kuhn Tucker conditions under such a scenario are still based on the same objectives function (..) except that in this case the amount of credit K, is treated as one of the parameters that is exogenously determined by the lender. The first order conditions for the interior solution are :

$$\frac{\partial L}{\partial q_{xhm}} = \lambda_2 q_{xhm} - p_{xhm}(1+\lambda_1) = 0\,,\ \lambda_1 > 0 \qquad (13)$$

Since the constraint is binding we must solve the optimum quantities of q_{xhm} and λ_1 as follows:

$$q^c{}_{xhm} = \quad q^c{}_{xhm}(p_{hm}, p_{lm}, p_{xhm}, z^q, E, K) \qquad (14)$$

The superscript c refers to the constrained case.

The difference between the two (constrained and constrained) is that in the constrained case farmers are unable to buy optimal quantities of hybrid maize input q_{xhm}. The amount of credit therefore becomes an important determinant of the farmer's ability to adopt hybrid maize. The amount demanded for hybrid maize input does not only depend on the prices of maize and other inputs but also on the amount of credit (K) available to the household.
The hypothesis to be empirically tested is that while access to credit (K) does not influence the adoption decision for the liquidity unconstrained farmers, it does so for the constrained.

4.0 Empirical Model

Our empirical strategy starts by categorizing households into credit constrained and unconstrained regimes. The elicitation approach allows us to capture whether or not a household is credit constrained by directly asking the household whether they needed more credit for its investment activities. Through a series of questions it is possible to know whether or not a household had excess demand (ED) for credit in a given recall period. The procedure allows for the treatment of excess demand for credit (ED) =(Demand –Supply), as a latent variable for each household *h*. Following this procedure it is not possible to assess the magnitude of the constraint, instead only an indicator of whether or not the household is credit constrained is observed (Gilligan *et al.,* 2005). The specification for the two categories of households can thus be written as follows:

$$k_h = 1 \text{ if } ED^*{}_h = X'_h\alpha + u_h \geq 0 \quad (15)$$

$$k_h = 0 \text{ if } ED^*{}_h = X'_h\alpha + u_h \leq 0$$

Where:

X_h represents household and farm characteristics that determine credit demand as well as characteristics of the household and the lending institution that determine the supply of credit

u_h is a random error term with zero mean capturing stochastic factors affecting both the demand and supply

Based on the theoretical framework presented earlier, the underlying assumption in assessing the effect of credit on adoption is that adoption *S* is a function of a vector, X consisting of exogenous variables and endogenous credit access, K, such that:

$$S = S(X', K, ; \beta) + \varepsilon_i \quad (16)$$

In this specification credit access K is endogenous because factors that affect the household's access to credit K may also affect the household's share of land allocated to hybrid maize. In order to solve this problem Zeller et, al (1998) recommend a simultaneous modeling of both the adoption decision and access to credit. As such, an extra equation is required to estimate the predicted access to credit, K expressed as

$$K = K(X', w; \gamma) + \omega_i \quad (17)$$

The theoretical framework outlined earlier postulates that credit access K is only an important variable for adoption among households that are credit constrained. The adoption of hybrid maize by a credit constrained household can thus be specified as follows:

$$S^c = S^c(X^{'}, K,; \beta) + \varepsilon_i \quad (18)$$

[3] $$K = K(X^{'}, w; \gamma) + \omega_i \quad (19)$$

Where:

$X^{'}$ is a vector of characteristics that affect both the adoption decision and the endogenous credit access, K,

$w =$ is a vector of instruments correlated with credit access but not with adoption,

ε_1 and ε_2 are random error terms, where as

β, γ are vectors of coefficients.

As for the unconstrained households, since it is assumed that credit access does not affect their decision to adopt hybrid maize, credit access, K, should have no impact on adoption. The specification is as follows:

$$S^u = A^u(X,; v) + \eta \quad (20)$$

where: v and η are a coefficient to be estimated and the error tem, respectively. The estimation of equations for the two regimes, thus the credit constrained regime and the unconstrained regime is done using a switching regression approach. Estimating the two equations separately is used as a counterfactual test of whether or not credit access affects adoption among constrained households. In the empirical estimation we include the predicted access to credit as one of the explanatory variables in both regimes.

Using equation 15 as a criterion function for whether or not a household is credit constrained and S to represent the dependent variable for adoption, we estimate an endogenous switching regression model as specified in Maddala, (1986) of the following form

[3] Results for this equation are not discussed in this paper but can be requested from the authors

$$S_h^{\ c} = W_{1h}^{'}\phi_1 + v_{1h} \text{ if } k_h = 1 \quad (21a)$$

$$S_h^{\ u} = W_{2h}^{'}\phi_2 + v_{2h} \text{ if } k_h = 0 \quad (21b)$$

where

$$\phi_i = [\delta_0, \beta_1 .... \beta_n]$$

$$W_{ih}^{'} = \lfloor X_h^{\ '}, \hat{K} \rfloor$$

$v_{ih} = \varepsilon_i$ for *i*=1 if the household is credit constrained and *i*=2 if unconstrained.

The endogeneity in a switching regression comes from the fact that we allow for correlation between the error terms in the credit constraint criterion function (15) and the equations of interest (21a) and (21b). Thus the error terms v_{1h}, v_{2h}, and, u_h are assumed to be jointly normally distributed with zero mean and the following covariance matrix.

$$\sum \begin{bmatrix} \sigma_{11} & \sigma_{12} & \sigma_{1u} \\ \sigma_{12} & \sigma_{22} & \sigma_{2u} \\ \sigma_{1u} & \sigma_{2u} & \sigma_{uu} \end{bmatrix}$$

The switching regression model accounts for the fact that each household has a non-zero probability of being credit constrained in each period, that this probability varies depending on household characteristics, and that only one realization of these probabilities is observed in each period (Gillgan *et al.,* 2005). Consistent estimates of parameters ϕ_1 and ϕ_2 can be obtained by following a two step Heckman procedure of estimating the credit constraint equation in (15) as a Probit and estimating equation 21a and 21b separately, while correcting for the selection bias by including the inverse Mills ratio from equation 15 as a regressor in the two equations.

Following Feder, Just and Zilberman (1985) we define adopters as households that reported that they grew hybrid maize. The extent of adoption is defined as degree of use of a technology, which for this study is taken as the proportion of maize land that is allocated to hybrid maize. The decision of whether or not to adopt hybrid maize variety and how much land to allocate to hybrid maize can be estimated using a censored Tobit model (Zilberman and Just 1984) or a P-Tobit model (Deaton and Irish (1984). However, the main weakness with the Tobit model is that it only allows one type of zero observation, namely, *a corner solution*, since it is based on the implicit assumption that zeros arise only as a result of the respondent's economic circumstances (Martínez-Espiñeira, 2006). In the same context Moffat (2003) observes that in some cases there are household that would never take some positive values, (thus they would never adopt under any circumstances because they consider the technology to be inferior), then the use of a restrictive Tobit model without considering the group that would never adopt may give biased results. Deaton and Irish (1984) propose a relaxation of this restriction by considering the probability that one would never adopt. With respect to this study, let us assume that the proportion of households that are potential adopters of hybrid maize is *p,* such that the proportion of households that would never adopt hybrid maize is (*1-p*). The Tobit model would apply for the group of potential adopters while it wouldn't for the "never adopters" since the intensity of adoption would be automatically zero. This gave rise to the P-Tobit model with the following likelihood function (Moffat 2003):

$$LogL = \sum_{0} \ln\left[1 - p\Phi\left(\frac{x_i'\beta}{\delta}\right)\right] + \sum_{+} \ln\left[p\frac{1}{\delta}\phi\left(\frac{y_i - x_i'\beta}{\delta}\right)\right] \qquad (22)$$

Thus in addition to estimating β and δ the P-Tobit also estimates the p.

Nevertheless, as noted by Martínez-Espiñeira (2006), the P-Tobit model fails to analyze the factors that will make a respondent more or less likely to adopt a technology. A further generalization allows for the parameter *p* to vary according to respondent's characteristics. This gives rise to the Double-Hurdle model which is an improvement over a P-Tobit. The underlying assumption in the Double-Hurdle approach is that individuals make two decisions with regard to their willingness to grow hybrid maize. The first decision is whether they will allocate a positive amount of land to hybrid maize at all. The second decision is about the share of land that they will allocate, conditional on the first decision. The two decisions are, therefore, whether to grow hybrid maize and how much to grow. The importance of treating the two decisions independently lies in the fact that factors that affect one's decision to adopt may be different from those that affect the decision on how much to adopt. This implies that households must cross two hurdles in order to adopt. The first hurdle needs to be crossed in order to be a potential adopter. Given that the households is a potential adopter, their current circumstances then dictate whether or not they do in fact adopt- this is the 'second hurdle' (Moffat 2003). The Double-Hurdle model allows for the possibility that these two decisions are affected by a different set of variables. The advantage with this approach is that it allows us to understand characteristics of a class of households that would never adopt hybrid maize. Thus the probability of a household to belong to a particular class depends on a set of household characteristics.

Originally proposed by Cragg (1971), the Double-Hurdle model has been recently applied in a variety of areas. Martínez-Espiñeira (2006) cites the use of the Double -Hurdle model by Burton, Dorset and Young´s (1996), who model US food expenditure away from home; Yen and Jones (1997) who apply the model to alcohol consumption and US household consumption of cheese, respectively. Moffat (2003) used the model to model loan default. The Double-Hurdle model is a parametric generalization of the P-Tobit model in which the decision to adopt and the intensity of adoption are determined by two separate stochastic processes and therefore, two equations. The first equation in the Double-Hurdle relates to the decision to adopt and it can be expressed as follows:

$$d_i = 1 \text{ if } d^*_i > 0 \text{ and } 0 \text{ if } d^*_i \leq 0 \qquad (23)$$

$$d^* = z_i'\alpha + \varepsilon_i$$

d^*_i is latent adoption variable that takes the value of 1 if a household grew hybrid maize and 0 otherwise, z is a vector of household characteristics and α is a vector of parameters;

The second hurdle, which closely resembles the Tobit model is expressed as:

$$y_i = y_i^* \text{ if } y_i^* > 0 \text{ and } d_i^* > 0$$

$$y_i = 0 \text{ otherwise}$$

$$y^* = x_i'\beta + u_i \qquad (24)$$

where y_i is the observed response on how much land one allocated to hybrid maze, x is a vector of the household characteristics and β is a vector of parameters.

The decision of whether or not to adopt hybrid maize and about how much land to allocate to hybrid maize can be *jointly* modeled, if they are made *simultaneously* by the household; *independently*, if the are made *separately*; or *sequentially,* if one is made first and affects the other one as in the dominance model (Martínez-Espiñeira, 2006). If the independence model applies, the error terms are distributed as follows:

$$\varepsilon_i \sim N(0,1)$$
$$u_i \sim N(0,\delta^2)$$

If both decisions are made jointly (the Dependent Double - Hurdle) the error term can be defined as

$\varepsilon_i \mu_i) \sim BVN(0,\Upsilon)$ where

$$\Upsilon = \begin{bmatrix} 1 & \rho\delta \\ \rho\delta & \delta^2 \end{bmatrix}$$

The model is said to be a dependent model if there is a relationship between the decision to adopt and the intensity of adoption. This relationship can be expressed as follows:

$$\rho = \frac{\mathrm{cov}(\varepsilon_i \mu_i)}{\sqrt{\mathrm{var}(\varepsilon_i)\,\mathrm{var}(\mu_i)}} \tag{25}$$

if $\rho = 0$ and there is dominance (the zeros are only associated to non-participation, not standard corner solutions) then the model decomposes into a Probit for participation and a standard OLS for y.

Following Smith (2003) we assume that the error terms ε_i and μ_i are independently and normally distributed[4] and thus we have the following expression:

$$\begin{pmatrix} \varepsilon_i \\ u_i \end{pmatrix} N\left[\begin{pmatrix} 0 \\ 0 \end{pmatrix}, \begin{pmatrix} 1 & 0 \\ 0 & \delta^2 \end{pmatrix}\right]$$

[4] See Smith (2003) for a theoretical analysis of why there might little gain from modeling dependence

And finally, the observed variable in a Double-Hurdle model is $y_i = d_i y_i^*$

The log-likelihood function for the double hurdle model is:

$$LogL = \sum_0 \ln\left[1 - \Phi(z_i'\alpha)\Phi\left(\frac{x_i'\beta}{\delta}\right)\right] + \sum_+ \ln\left[\Phi(z_i'\alpha)\frac{1}{\delta}\phi\left(\frac{y_i - x_i'\beta}{\delta}\right)\right] \quad (26)$$

Empirical results by both Moffat (2003) and Martínez-Espiñeira (2006) reveal that the Double-Hurdle model gives superior results to those obtained from Tobit and P-Tobit models. Thus in this study we estimate the decision to adopt and the extent of adoption using a Double-Hurdle model.

5.0 Data

The data used in this analysis draws from a survey of households conducted by the International Food Policy Research Institute (IFPRI), and the Department of Rural Development at Bunda College of Agriculture in 1996 (for details see Diagne and Zeller 2001). The survey was conducted in three rounds, however this study used data from the first round of the survey. The objective of the IFPRI study was to investigate the effects of access to credit on household welfare. The survey covered 404 households selected via stratified random sampling method, from the three regions and from 5 districts of Rumphi, Nkhotakota, Dowa and Dedza and Mangochi. The survey questionnaire consists of seven modules. Only 3 modules were of relevance to this study, namely, household demographics, crop and livestock production and credit and savings. The data is available from on request from the International Food Policy Research Institute (IFPRI).

Descriptive statistics for selected variables included in the adoption model differentiated by the adoption status are presented in Table 1. They include socio-economic characteristics such as age, sex and education level of a household head. We also include wealth status indicators such as land size, the value of assets, amount of off farm income and market access factors (supply related factors) such as credit, distance to markets, and access to the extension services. Our a priori expectation is that wealth proxy variables will have a positive effect on the adoption of hybrid maize (Feder *et al*., 1985). We expect that access to credit will increase adoption among credit constrained households through the relaxation of the liquidity constraints. We expect farmers that are close to input and output markets as well as close to extension service centers to adopt hybrid maize due to the reduction in transaction costs. Descriptive statistics indicate that adopters have high off-farm incomes (MK 3050) than non-adopters (MK 2167). At the time of the survey, 1 US-dollar was worth 44 Malawi Kwacha (MK). There are no marked differences in terms of gender, age and education of household head between adopters and non-adopters. However, adopting households are significantly (at 5 percent level) larger (4.9 persons) than non adopters (4.3 persons). It is also observed that adopting households have significantly larger ($P<0.05$) land holdings (1.8 hectares) than non adopters (1.5 hectares). With regards to wealth, adopters are wealthier with significantly larger asset values (MK 2762) than the non adopters (MK 1006). In addition, adopters have significantly higher levels of access to formal credit than non-adopting households. A larger proportion of non-adopters (86%) than adopters (50%) rely on agriculture as their primary occupation. Other major sources of livelihoods for adopters are self employment (10%) and wage employment (15%).

Table 1: Means of selected variables, differentiated by adoption status for hybrid maize

Variable	Adopters (n=161)	non-adopters (n=243)	Total (n=404)
Yearly off-farm income (MK)	3050.40	2167.86	2694
Female- headed (%)	71.4	67.5	70
Age of household head(years)	45	47	46
Years of schooling of household head	3.6	2.8	3.3
Years of schooling of spouse	2.6	2.1	2.4
Household size	4.9	4.3	4.7
Number of adult males (15-64 years)	1.2	1.1	1.1
Number of adult females(15-64 years)	1.4	1.3	1.3
Land holding size in hectares	1.8	1.5	1.7
Number of persons per hectare cultivated	1.4	1.2	1.3
Credit access (MK/year)	346	232	300
Percentage of households owning livestock	53	65	58
Value of assets owned (MK)	2762	1006	2036
Occupation of household head			
Farming	50	86	65
Household worker	3	4	3
Wage laborer	15	3	10
Trade	10	2	6
Other self-employment	17	1	11
Unemployed	1	2	1.2
Other	4.1	1.5	3.0

Source: Own calculation from RDD/IFPRI Rural Finance Survey

6.0 Results and discussions

6.1 Full sample estimates

Table 2 presents results from the double hurdle model of determinants on adoption. In addition to credit variables we include other variables that are theoretically linked to technology adoption. We estimate three separate equations and observe differences in the impact of credit between credit-constrained and unconstrained households. Columns 1 and 2 present estimates of the adoption model for the full sample of farmers. Results show that access to credit has a positive and significant effect on the probability of adoption, while its effect on the extent of adoption is not significant. The implication from this finding is that access to credit increases the likelihood that a household will potentially adopt hybrid maize but conditional on adoption, access to credit does not lead to high levels of adoption. One explanation to the insignificant effect of credit on the extent of adoption in the full sample could be that the credit provided is not high enough to significantly improve the intensity of adoption. This is consistent with the finding by Diagne and Zeller (2001) that the credit limits granted by formal lenders in Malawi were relatively small in relation to the amount of credit demanded. Zeller and Diagne (2001) therefore recommend to gradually increase loan sizes to repeat borrowers. The other explanation could be that not all credit is used for the production of hybrid maize which is also confirmed by Diagne and Zeller (2001). Nevertheless, the finding that credit significantly increases the likelihood of adoption is inline with a priori expectations and in concurrence with findings from a number of studies that have shown that the lack of access to credit significantly inhibits the adoption of high yielding varieties even when fixed pecuniary costs are not large (Feder *et al.,* 1985).

Other than credit, a number of other variables returned significant signs in the full sample estimates. The amount of off- farm income had a positive and significant effect on the likelihood of adoption but it returned a negative and significant effect on the extent of adoption. Theoretically, off-farm income can help to overcome a working capital constraint or may even finance the purchase of a fixed investment type of innovation. Empirical evidence of similar findings has been reported by Feder et al (1985). These results imply that households with high off-farm income have a higher potential of becoming adopters, thus they are more likely to pass through the first hurdle than those with less off-farm-income. However, conditional on adoption households with high off farm income will allocate smaller portions of land to hybrid production. One reason is that households with high off-farm incomes are located in Nkhotakota and Mangochi districts where maize is not a prime crop and where households derive most of their livelihoods from fishing in the lake or fish selling such that the amount of off-farm income earned is not reinvested into hybrid maize production. The average off-farm incomes for Nkhotakota and Mangochi were MK 5808 and MK 4440, respectively. These incomes were twice as high as the average off-farm income for the sample of MK 2600.

Regarding the age of the household head, results indicate that it has a negative and significant effect on the probability of adoption. The age of household head had no effect on the extent of adoption. Old age happens to be one of the human capital characteristics that have been frequently associated with non-adoption in most adoption studies. Among the several reasons that could explain the negative effect of age on adoption is the fact that older farmers have a tendency to stick to their old production techniques and that they are usually unwilling to accept change. In addition young people are associated with a higher risk taking behavior than the elderly. At the time of the survey, more than 60 percent of the heads of households were more than 40 years old.

The size of a household has a positive and significant effect on the probability of adoption. However, it has a negative and significant effect on the extent of adoption for hybrid maize. The positive effect on the probability of adoption can be explained by the fact that labor is an important input in the production of maize and therefore, larger households have abundant labor required for maize production. The negative effect of household size on the extent of adoption can be explained by the fact that once the decision to grow hybrid maize is made based on abundant labor available, the extent of adoption will depend on the ability of the household to finance the purchase of inputs required for the cultivation of hybrid maize. This is particularly true because hybrid maize requires more capital for the purchase of fertilizer and seed than it requires labor because it is not labor intensive.

Households that received free inputs in form of fertilizer and seed were more likely to adopt hybrid maize than those that did not but conditional on adoption, free inputs had no effects on the extent of adoption. This can be explained by the fact that the amount of free inputs distributed in form of fertilizer and seed are usually the same across households and that they are usually enough for the cultivation of very small portions of land of about 0.25 acres.

Table 2: Determinants of adoption – Double-Hurdle model estimates

	Pooled of full sample (n=404)		Credit Constrained (n=223)		Credit unconstrained (n=181)	
	First hurdle	Second hurdle	First hurdle	Second hurdle	First hurdle	Second hurdle
	Coefficient (std.Errors)	Coefficient (std.Errors)	Coefficient (std.Errors)	Coefficient (std.Errors)	Coefficient (std.Errors)	Coefficient (std.Errors)
Off farm income	0.0011***	-0.0012***	0.0001	-0.0024***	0.0000	-0.0004
	(0.0001)	(0.0003)	(0.0001)	(0.0006)	(0.0001)	(0.0003)
Gender (1=male)	-0.1048	0.4032	-0.5364	6.7265	-0.8836	18.5642**
	(0.2463)	(4.6639)	(0.4079)	(5.3282)	(0.6020)	(7.7599)
Age household head	-0.0148*	-0.2382	-0.0131	-0.4992**	-0.0039	-0.3825*
	(0.0076)	(0.1455)	(0.0176)	(0.2389)	(0.0143)	(0.2036)
Assetvalue	0.0001	0.0005	0.0004**	-0.0008	0.0000	0.0002
	(0.0001)	(0.0004)	(0.0002)	(0.0008)	(0.0001)	(0.0003)
Household size	0.2684***	-3.0063**	0.3866***	-2.8244	0.1470	-3.8909***
	(0.0732)	(1.3570)	(0.1266)	(2.0886)	(0.1645)	(1.1912)
Total land holding	-0.0419	-1.6460	-0.4282**	0.0544	0.8746***	-2.2721**
	(0.1119)	(1.4963)	(0.2108)	(2.8510)	(0.2307)	(1.1093)
Education head	0.0466	-1.3151	-0.2748	-0.6274	-0.7890	-9.6408*
	(0.2157)	(5.3272)	(0.5051)	(7.3753)	(0.5566)	(5.0293)
Free inputs	0.9796**	3.2644	0.6274	12.7164***	1.0161	-13.3996**
	(0.3832)	(3.7366)	(0.8003)	(4.3385)	(0.8043)	(6.2884)
Tobacco growing household	-0.0586	-6.3529	0.9890	-5.4611	-1.0685**	6.0363
	(0.3450)	(6.7016)	(0.7466)	(12.6465)	(0.4776)	(5.3914)
Distance to extension office	-0.0116	1.4238	-0.3370**	1.0640	0.0425	1.1292
	(0.0411)	(1.1182)	(0.1564)	(2.4644)	(0.0951)	(0.8765)
Distance to market	-0.0023	0.5269	-0.0855	0.3529	0.0304	1.2907**
	(0.0250)	(0.5717)	(0.0696)	(0.4953)	(0.0628)	(0.5407)
Formal credit	0.0013***	0.0016	0.0001	0.0334***	0.0000	0.0013
	(0.0004)	(0.0020)	(0.0005)	(0.0123)	(0.0001)	(0.0012)
Informal credit	-0.0003	0.0019	0.0000	0.0017	0.0006	0.0040
	(0.0006)	(0.0059)	(0.0014)	(0.0106)	(0.0005)	(0.0038)
Land pressure	-0.2389***	4.5916***	-0.3476***	5.7717***	-0.1953*	3.9224**
	(0.0554)	(1.5095)	(0.1146)	(2.1543)	(0.1135)	(1.7802)
Mangochi	1.6047***	17.3987**	-0.3120	21.2384*	2.7333**	20.2055**
	(0.4126)	(8.6653)	(0.8298)	(10.9443)	(1.1144)	(8.3566)
Nkhota	0.5178	-5.1923	-2.1100*	2.4047	1.1728	20.8476*
	(0.5400)	(11.2355)	(1.2297)	(13.0428)	(1.1626)	(12.1804)
Rumphi	0.5078	-7.4643	-0.4602	-20.3768	4.0824**	4.4304
	(0.6550)	(11.4892)	(2.2966)	(18.6330)	(1.7858)	(11.186)
Dedza	-0.7269**	-20.7612**	2.2634	-60.8863***	0.5016	-17.5358**
	(0.2986)	9.4830)	(1.4331)	(11.5352)	(0.5316)	(7.6329)
Lambda			-1.2139**	10.3686	1.4480***	-7.9923**
			(0.6084)	(15.4296)	(0.3624)	(3.1410)
_cons	0.0404	48.5584***	3.2837*	46.3980**	-3.0855**	53.7061***
	(0.6098)	(15.6481)	(1.9231)	(19.5353)	(1.4051)	(19.5569)
/lnsigma		3.18238***		3.17436***		2.8668***
		(0.0574)		(0.0710)		(0.07489)
Sigma		24.1040***		23.91169***		17.58148
		(1.3842)		(1.6260)		(1.3168)
No. of obs		404		223		181
Chi-square		112.31***		208***		120.22***
LL-function		-1152.109		-609.131		-532.6219

Source: Own calculation from RDD/IFPRI Rural Finance Survey

Land pressure, which is measured as the number of persons per hectare has a negative and significant effect on the probability of adoption, but conditional on adoption households with more individuals per hectare allocate more land to hybrid maize. Experience has shown that households with high land pressure are also likely to be poor households hence less likely to finance the purchase of costly innovations. However, upon surpassing the first hurdle, households with high land pressure will intensify their adoption of an improved variety to maximize productivity required to meet their food and cash requirements from the small size of land. In most adoption literature, high land pressure has been described as a prerequisite for agricultural intensification. Results indicate that households in Mangochi and Dedza are more likely to allocate larger portions of land to hybrid maize than households from other districts. The remain explanatory variables such as gender, education, land holding as well as markets access variables such as distance to market and distance to extension office were not significant in the full sample estimates.

6.2 Constrained versus unconstrained households

Columns 3-4 and columns 5-6 present estimates of the switching regression model for the credit constrained and credit unconstrained households, respectively.[5] Results from the credit constrained regime in columns 3 and 4 indicate that credit has a positive and significant effect on the extent of adoption of hybrid maize but it had no effect on the likelihood of adoption. The implication from these findings is that once credit constrained households decide to adopt hybrid maize, credit significantly increases their ability to finance the purchase of inputs required for the production of hybrid maize which leads to an expansion of the area under hybrid maize. Therefore, conditional on adoption, credit constrained households with higher amounts of credit allocate more land to hybrid maize production. In the study area in particular, formal credit is provided for the production of tobacco as well as for off-farm employment activities.

In concurrence with the null hypothesis that credit will have no effect on the adoption of hybrid maize among unconstrained households, results in columns 5 and 6

[5] The results for the switching regression model are estimated using a Heckman selection model to estimate parameters in each regime while adjusting standard errors accordingly. Estimates of the first stage Probit model on credit constraints were presented earlier.

reveal that indeed credit had no effect on both the likelihood of a adoption as well as the extent of adoption in the unconstrained regime. The value of assets which was used as a proxy for household wealth had a positive and significant effect on the likelihood of adoption in the credit constrained regime but it had no effect on the likelihood of adoption in the unconstrained regime. Land holding size reduces the likelihood of adoption in the credit constrained regime while it increases the likelihood of adoption in the unconstrained regime. This is not a surprising finding because as observed by Weil (1970) the negative relationship between adoption and land holding size may be caused by credit constraints. Weil suggests that capital may be more available for larger farms, so that even though all farms may wish to adopt, larger farms are more likely to do so. Thus, households with larger holdings are also likely to be wealthier, with increased ability for self financing the purchasing of inputs but when such households are credit constrained then their adoption rate is negatively affected. The negative effect of land holding on the extent of adoption inn the unconstrained regime implies that smaller farmers exhibit higher intensities of hybrid maize adoption than larger farms. Feder *et al.* (1975) suggested that the phenomenon may arise because small farms will farm land more intensively to meet subsistence needs

The gender of household head was significant only in the unconstrained regime. Thus male headed households that were not credit constrained allocated larger proportions of their land to hybrid maize cultivation than female headed households. Of interest in the unconstrained regime is the fact that while land holding increases the likelihood of adoption, it negatively affects the extent of adoption. While the land allocated to tobacco was insignificant in the constrained regime, results show that tobacco growing households that are unconstrained are less likely to grow hybrid maize. Free input distribution among unconstrained households does not necessarily translate into increased hybrid maize production. The main reason is that the majority of unconstrained households that received free inputs were from Mangochi and Nkhotakota where maize farming is not popular. Hence, because of such mistargeting of credit to on average wealthier households, the expected effects on hybrid maize adoption and production were not materializing.

7.0 Conclusions and policy implications

The current policy emphasis on credit as a development tool coupled with the limited availability of funds for credit implies that targeting credit to those that really need it has become a crucial issue. In addition, it is theoretically expected that credit provided at market interest rate results into marginal benefits among credit constrained households but does no welfare enhancement for unconstrained households. Therefore, achieving high economic efficiency in credit allocation requires targeting credit constrained households. This paper has investigated the impact of access to credit among households that differ in their credit constraint status. Using a switching regression approach we investigated determinants of adoption of hybrid maize using a Double-Hurdle model due to a hypothesis that factors that affect the decision to adopt hybrid maize may be different from those that influence the extent of adoption.

Results reveal that factors that influence the decision to adopt hybrid maize are not necessarily the same factors that affect the extent of adoption. Results also indicate that factors that affect adoption decisions among credit constrained households are different from those that affect adoption in the unconstrained regime. For, example, while credit had a positive effect on adoption in the constrained regime, it had no effect among unconstrained households. The effect of land size on adoption is another example of variables with an opposite effect between the two regimes. Results indicated that while larger land holdings lead to increased adoption among the unconstrained regime, it has a negative effect on adoption in the constrained regime probably due to credit constraints. An interesting lesson from this study is that it is important to consider the two stages of adoption separately when assessing strategies for promoting agricultural technologies because factors that affect the decision to adopt are different from those that affect the decision on the extent of adoption.

The fact that credit access had a higher impact on the adoption of hybrid maize among credit constrained households justifies the need for credit targeting to achieve high economic efficiency. Second, most of the formal credit from formal credit institutions in Malawi to rural households is in the form of in-kind credit, namely fertilizer and seeds either for hybrid maize and tobacco. Our results show that – unless such credit is provided to credit-constrained households – the current practice of loan delivery aimed at increasing hybrid maize production fails to achieve the objective of increasing hybrid maize share. Farm households receiving such in-kind credit simply at best substitute own financing for credit, or worse, they will on-sell the hybrid maize seed and fertilizer presumably at a loss, or use it for other crops. In any case, formal credit institutions in Malawi may reconsider the practice of in-kind loans, considering that the net welfare benefit of cash credit for rural farm households with multiple sources of income, investment and consumption opportunities is likely to be higher than the one generated by in-kind credit.

Third, our results indicate that although credit access increases the likelihood of adoption, it does not influence the extent of hybrid maize area cultivated. This indicates that loan sizes may be too small for making a significant impact on the cultivated area. The formal institutions may reconsider their practice of giving standardized loan sizes, and adopt a more demand-oriented flexible policy that rewards repeat borrowers with impeccular repayment records with gradually increasing larger loans. Among hybrid maize farmers, this change in policy is likely to increase the area of hybrid maize grown in Malawi. Fourth, only less than 6 percent of smallholders in Malawi have currently access to credit. Expanding the existing rural credit system to more smallholders will be crucial for fostering the adoption of higher-value food and cash crops, such as hybrid maize.

Last, poverty in rural Malawi is widespread and deep. The poorest of the poor among rural farm households need to be targeted through safety net schemes – not credit- in order to enable these households to adopt higher value crops while ensuring food security after droughts or other natural disasters. Hence, credit is only of relevance to a smaller set of rural households in Malawi. Other constraints, such as extreme vulnerability and poverty, or lack of market access and road infrastructure, need to be addressed by other policy instruments.

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A NNEX 1

Descriptive statistics of regression variables

Variables	Mean	Std. Deviation	Minimum	Maximum
Dependent Variables				
Whether adopted (1=yes, 0=no)	0.596535	0.491201	0	1
Percentage of land under hybrid maize	27.35657	27.32174	0	99
Independent variables				
Yearly off-farm income (MK)	2694.354	7481.599	-28921	77700
Gender of household head (1=male)	0.722772	0.448185	0	1
Age of household head(years)	45.13119	13.58404	20	86
Value of assets owned (MK)	3433.017	8112.252	100	126920
Household size	4.361386	1.931351	1	12
Land holding size(ha)	2.175743	1.956425	0	22
Years of schooling of head	0.759901	0.427673	0	1
Whether receive free inputs (1=yes)	0.160891	0.430079	0	5
Tobacco growing household (1=yes)	0.225248	0.418263	0	1
Distance to Market	6.267327	7.221956	0	23
Distance to the extension office	2.242574	3.60322	0	15
Formal credit access (MK/year)	716.7129	1444.45	0	15998
Informal credit access (MK/year)	176.6856	303.4811	0	2020
Number of persons per hectare cultivated	3.081683	2.640731	0	16
Mangochi	0.24505	0.43065	0	1
Nkhota kota	0.175743	0.381073	0	1
Rumphi	0.190594	0.393257	0	1
Dedza	0.252475	0.434971	0	1