The impact of credit constraints on the adoption of hybrid maize in Malawi

Franklin SIMTOWE, Manfred ZELLER**, Aliou DIAGNE****

* Corresponding author: International Crops Research Institute for the Semi Arid Tropics (ICRISAT) – Nairobi, PO BOX 39063, Nairobi, Kenya
e-mail: fsimtowe@yahoo.com

** University of Hohenheim, Institute of Agricultural Economics and Social Sciences in the Tropics and Subtropics, Germany

*** Africa Rice Centre, Cotonou, Benin

Summary *– This paper investigates the impact of credit constraints on the adoption of hybrid maize among rural households in Malawi. To address the endogenous and binary nature of the household's credit constraints status, we employ a treatment-effects model to consistently estimate the effect of credit constraints. Results reveal that after effectively correcting for endogeneity, credit constraints have a negative and significant effect on the amount of land allocated to hybrid maize. Results also show that farmers with larger land holdings allocate more land to hybrid maize. Although less likely to report credit constraints, older farmers allocate less land to hybrid maize than younger farmers. These findings suggest that there is scope for increasing the cultivation of hybrid maize in Malawi if credit is targeted at younger farmers that are credit-constrained.*

Keywords: *credit constraints, hybrid maize, adoption, treatment-effect, endogenous, Malawi*

L'impact des contraintes de crédit sur l'adoption du maïs hybride au Malawi

Résumé – Cet article étudie l'impact des contraintes de crédit sur l'adoption du maïs hybride au sein des ménages ruraux au Malawi. En raison de la nature endogène et binaire du statut des contraintes de crédit d'un ménage, nous utilisons le modèle d'effet de traitement pour estimer l'effet des contraintes de crédit. Les résultats indiquent que les contraintes de crédit ont un effet négatif et significatif sur la quantité de terre allouée au maïs hybride. Les résultats prouvent également que les producteurs possédant les plus grandes superficies de terres allouent une superficie plus grande à la culture du maïs hybride. Bien que probablement moins attribuable aux contraintes de crédit, les producteurs les plus âgés allouent moins de terre au maïs hybride que les producteurs plus jeunes. Ces résultats suggèrent qu'il y aurait possibilité d'augmenter la culture du maïs hybride au Malawi si le crédit ciblait les jeunes producteurs contraints par l'accès au crédit.

Mots-clés : contraintes de crédit, maïs hybride, adoption, effet de traitement, endogène, Malawi

JEL descriptors : C31, D13, Q12, Q14

1. Introduction

Crop productivity improvement through the use of modern varieties such as hybrid maize is popularly believed to offer hope for a green revolution in the developing countries. Consistent with this notion, some authors argue that the maize green revolution occurred in some Eastern and Southern African countries such as in Zimbabwe (Eicher, 1995) and in Kenya (Hassan *et al.*, 1998; Karanja, 1993) after decolonization, but it fizzled in the mid 1980s. Carr (1997), in his paper "a green revolution frustrated", observes that Malawi briefly experienced a green revolution in the early 1990s when the use of fertilizer and hybrid seed had been adopted on almost half of the total maize area. Yields of fertilized hybrid maize had increased to about three times those obtained under traditional practices, which led a number of international observers to classify Malawi's experience as an example of an African "green revolution".

However, due to a number of policy changes, including changes in subsidy policy, liberalization of input and output markets, and the floating of the currency, among others, farmers could not afford to purchase hybrid maize seed and fertilizer. In 1995/96 season, for example, smallholder farmers were only able to purchase hybrid maize seed sufficient to plant 7% of the maize area. Local maize has a flint grain texture, highly valued by Malawian smallholders because of the higher flour-to-grain extraction rate. However, the principal disadvantages of local maize such as its tall plants, long growing season, low grain-to-stover ratio, and relatively low yield, particularly when fertilizer is used (CYMMYT, 1998), make it less favored by policy makers. Studies by CYMMYT have further revealed that despite low to zero levels of nitrogen and under modest management levels, the maize hybrids grown in Malawi yield more than the local maize even during years of moisture stress. A further analysis on the profitability of maize indicates that under most assumptions (*e.g.*, for most types of farmers), the yield advantages of using hybrid seed and fertilizer translate into economic advantages (CYMMYT, 1998) suggesting that the growing of hybrid maize is advantageous in several aspects. In a partial budget analysis of demonstration data from 1989 through 1993, Jones and Heisey (1994) observe that hybrid maize was profitable for smallholders under several pricing scenarios and management environments. However, Smale and Phiri (1998) report that at the 1997 fertilizer-maize price ratios (when subsidies had been removed), maize production was unprofitable for commercial production by smallholders, but it was profitable in the production for home consumption. Smale and Phiri (1998) further report that farmers almost unanimously wanted to grow hybrid seed, but most could not purchase as much seed as they wished due to the high seed costs.

The provision of micro-credit to farmers is seen as an effective strategy for promoting the adoption of improved technologies. It is believed that access to credit promotes the adoption of technologies through the relaxation of the liquidity constraints as well as through the boosting of household's risk-bearing ability. With the 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). Consistent with this notion, Smale (1995)

observes that in addition to taste preferences, on-farm storage constraints and risk aversion (Simtowe *et al*., 2006), credit constraints are responsible for the low adoption of hybrid maize due to its requirements for costly seed.

Recognizing the potential contribution of credit in enhancing the adoption of hybrid maize among smallholders, the government of Malawi pursued a credit policy aimed at promoting hybrid maize production from the early 1980s through to the 1990s. The government of Malawi started providing joint liability loans to smallholder farmers as far back as 1973 through the Smallholder Agricultural Credit Administration (SACA), three years before the Grameen Bank was created (Diagne *et al.,* 2000a). The main purpose of the credit was to promote smallholders' production of high value crops (first maize, then later in the 1990s also tobacco, with hardly any loans for hybrid maize seed from the late 1990s unless tied to tobacco loans). The credit was mainly provided to farmers in the form of in-kind loans such as fertilizer and seed. However, despite concerted efforts by the government and more recently non-governmental organizations in promoting the cultivation of hybrid maize, the adoption rate remains low and in 2003, more than half of the total maize land was allocated to local varieties (Government of Malawi, 2004). In 2003 an upward trend in the hybrid area was noted and again in 2006, which have been associated with an increase in the supply of subsidized seed.

A substantial amount of the literature has reported on the impact of access to credit on adoption, and there is considerable research showing the positive impact of credit on adoption. For example, Feder and Umali (1993) and Cornejo and McBrid (2002) review factors that affect technology adoption and 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. 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" – 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. In Malawi, as elsewhere, most adoption studies have not taken into account the credit constraint status of a household and those that attempted to do so did not adequately control for endogeneity.

Thus this paper aims to fill that gap by investigating the extent to which credit constraints have impeded the smallholder farmer's adoption of hybrid maize in Malawi. Adopters of hybrid maize are defined as households that planted first generation hybrid seed [1] as opposed to recycled hybrid seed. The study uses a treatment effects model.

[1] During the survey an attempt was made to ascertain whether or not the seed used was first generation. Other studies have shown that recycled hybrid maize produces lower yield than local maize such that farmers are less likely to plant recycled hybrid maize.

The treatment effects model is particularly appropriate for this kind of analysis due to the presumption that credit constraints are endogenous in the adoption model. Using the direct elicitation approach proposed by Jappelli (1990), Diagne *et al*. (2000b) and Sawada *et al.* (2006), households are classified into credit constrained and unconstrained regimes. The treatment effects approach combines the estimation of the probability of being credit constrained as well as the estimation of the impact of credit constraints on the adoption of hybrid maize. Data used in this study is from Malawi collected by the International Food Policy Research Institute (IFPRI) in 1994. Results show that due to endogeneity of the credit constraint status of a household, the use of Ordinary Least Square and the Tobit estimates do not provide consistent estimates. Instead, we find that the treatment effects model that controls for the endogeneity of the credit constraints provides reliable estimates that reveal that credit constraints reduce the amount of land allocated to hybrid maize. The paper is organized as follows: in section 2 we present a review of maize production in Malawi and the role of credit. In section 3 we present the empirical framework and an econometric specification of the empirical model. The data used for the estimation is described in section 4. In section 5 we present and discuss results, while section 6 is the conclusion.

2. 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 arable land is allocated to maize production (Government of Malawi, 2004). It is also noted that despite efforts to diversify, the area of land allocated to maize production continues to increase. Carr (1997) notes that the continued rise in the land allocated to maize could be attributed to the fact that maize is a C4 [2] 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 and in combination with the lack of inputs that accompany the maize production, yields remain low. This contributes significantly to food insecurity as more than 60 percent of households run out of food four months before the next harvest (World Bank, 1996). The response by the Government of Malawi has been the introduction of hybrid maize suited for both the climate and food preferences of farmers.

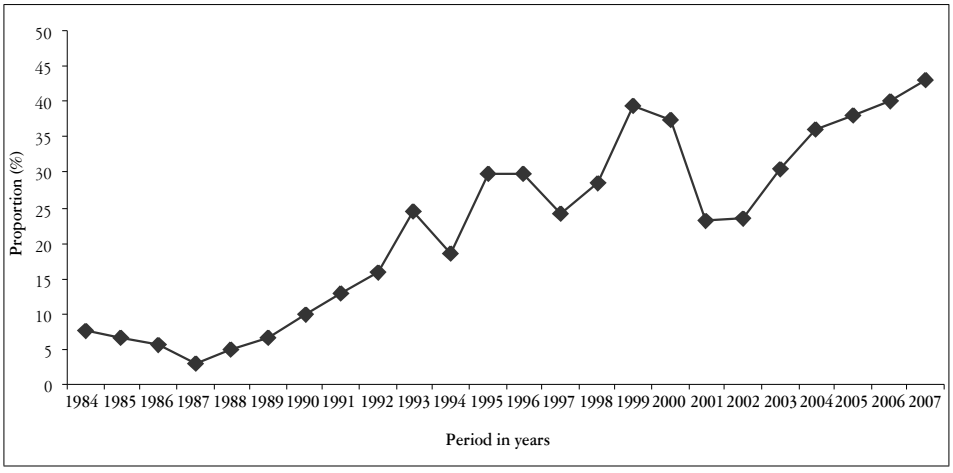
To achieve their policy of intensifying maize production through the use of hybrid maize seed and fertilizer, in 1973 the Government embarked on an ambitious credit program based on joint liability lending. Agricultural extension officers were given the tasks of overseeing the functioning of the credit groups and monitoring loan repayments. 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

[2] C4 plants are plants found principally in hot climates whose initial fixation of carbon dioxide in photosynthesis is by the hatch slack kortshak (hsk) pathway. The presence of the hsk pathway permits efficient photosynthesis at high light intensities and low carbon dioxide concentrations which make C4 plants more efficient at fixing carbon dioxide than other plants. Most species of this type have little or no photorespiration.

Malawi to register the highest repayment rates (95 percent) for a number of years. It is believed that the rapid increase in hybrid maize seed and fertilizer use in the 1990s was encouraged by a sharp rise in the supply of credit to smallholder farmers. 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. [3]

Figure 1 presents the trend in the share of land allocated to hybrid maize from 1984 to 2007. Although there is a positive trend in the share of land allocated to hybrid maize (as shown by the increase from about eight percent in 1984 to forty percent in 2007), there have 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 Smallholder 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 smallholder 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 upward trend resumed after 1994 due to the large

Figure 1. **Share of maize land allocated to hybrid maize production**



Source: Government of Malawi, Ministry of Agriculture statistics (various years) [3]

[3] Although these are the official statistics from the Ministry of Agriculture, they are based on national crop estimates, whose methodology has been under question for some time. Furthermore the statistics might include the second generation seeds, which are not pure hybrids. The best way to capture this information could have been through seed sales statistics. However, in the absence of the seed sales statistics, these figures can be used as a reliable proxy of the amount of land cultivated from different varieties.

scale distribution of free fertilizer and hybrid maize seed. A sharp fall was experienced in 2001 and 2002, partly due to drought and failure in the subsidy programs, as well as due to the government's introduction of open pollinated varieties, but 2003 saw a recovery to 30 percent. The land allocated to hybrid steadily increased after 2003 largely due to the free input distribution programs and the subsidy program being implemented by the Government of Malawi. We note that since 1998 the Government of Malawi has been implementing such safety net programs as the Targeted Input Programs (TIP) (Gough *et al.*, 2002) whose major objective is to provide free agricultural inputs to poor households that lack the means for financing the purchase of agricultural inputs. However, the efficiency of such programs will largely depend on the extent to which they target the credit constrained. Consistent with this notion, Zeller *et al*. (2006) contend that profitable microfinance institutions will not have served their original objectives if the poorest are not among their clients. This study is pertinent in that it attempts to address two related questions: (*i*) "Who is credit constrained ?" and (*ii*) "can credit constraints explain the non-adoption puzzle for hybrid maize?". The findings of the study can be used as an input to a process of credit policy improvement as well as understanding how best to use credit as a tool for enhancing the cultivation of hybrid maize.

3. Theoretical framework and econometric specification of the empirical model

The analysis in the present paper is based on the hypothesis that credit constraints are a barrier to the adoption of improved technologies by most poor households. We start by presenting a framework of household consumption and credit constraints and then apply it to the adoption of hybrid maize. Following Diagne and Zeller (2001), Jappelli (1990), and Sawada *et al.* (2006), we construct a qualitative response model of endogenous credit constraint by defining an indicator variable of credit constraints cc. We do so by assuming that a household consumes some amount of goods, C, in a given period of time. Let C^* represent the optimal consumption in the absence of credit constraints. $C^* = C$ (the actual consumption) if the credit constraint is not binding; $C^* > C$ if the credit constraint is binding. The gap between optimal consumption and the actual consumption measures the existence or not of a credit constraint. We assume that the consumption gap is defined as $H^* = C - C^*$. According to Jappelli (1990), Sawada *et al.* (2006) and Gilligan *et al.* (2005), there are two factors that determine whether or not a household will face credit constraints. The first factor is the demand for credit which is the difference between household resource endowment and desired consumption. The second factor relates to the supply of credit by financial institutions. The optimal consumption C^* and the maximum available credit to the household can both be expressed as a linear function of observables such as the household's human and physical capital. A reduced form equation of the consumption gap can thus be written as follows:

$$H^* = w\gamma + \mu \tag{1}$$

$$cc = \begin{cases} 1 \; if \;\; H^* < 0 \\ 0 \; if \;\; H^* \geq 0 \end{cases}$$

where: w represents household and farm characteristics that determine credit demand as well as the supply of credit to the household; m is a random error term with zero mean.

A household is said to have a binding credit constraint if H*< 0 and thus $cc = 1$. The credit constraint is not binding if $H^* \geq 0$ and thus $cc = 0$.

The econometric model of the impact of credit constrains on the adoption of hybrid maize can be composed of two interrelated dependent variable models. The first model is a credit constraint equation (equation 1).

The second model relates to the adoption of hybrid maize in which the endogenous credit constraint status of a household is included as an explanatory variable as in the following equation:

$$y = \alpha cc + x_M \beta_M + \varepsilon \quad (2)$$

where y is the household's land allocated to hybrid maize in each reference season, x_M is a matrix of household specific socioeconomic and demographic characteristics that affect adoption decisions. The variable cc is an indicator of credit constraints which takes the value of one if the credit constraint is binding and zero otherwise and is assumed to have a negative effect on hybrid maize adoption. The last term ε is the error. The disturbance terms (μ, ε) have zero mean, bivariate normal distribution with a unit variance and $\rho_1 = Corr(\mu, \varepsilon)$. The covariate matrix is written as follows:

$$\begin{bmatrix} \sigma & \rho \\ \rho & 1 \end{bmatrix}$$

Green (2000) notes that if $\rho_1 \neq 0$, then μ and ε are correlated, and that an estimation of equation (2) is inconsistent for α and β.

We observe that hybrid maize is a relatively old technology in Malawi and that most farmers are aware of the technology. Therefore the estimation of the adoption rates and its determinants is less likely to suffer from what Diagne and Demont (2007) call "*non exposure*" bias and from "*selection bias*" which results into inconsistent estimates if the bias is not corrected.

To estimate the model of the impact of credit constraints on the adoption of hybrid maize, we use the treatment effects model. The treatment effects model estimates the effect of an endogenous binary treatment cc on a continuous, fully observed variable y, conditional on the independent variables x and w. The primary interest is in the regression function (equation 2). In the proposed treatment model, cc is the endogenous dummy variable indicating whether the treatment is assigned or not. The binary outcome treatment cc is modeled as the outcome of an unobserved latent variable cc*. It is assumed that cc* is a linear function of the exogenous covariate w and a random component u.

In this study, part of our objective is to show the importance of correcting for endogeneity when assessing the effect of credit constraints. We do so by estimating two additional regressions using the Ordinary Least Squares (OLS) and Tobit regression

in which the credit constraint status of a household is included as one of the independent variables without adequately controlling for endogeneity, and compare the results with those from the treatment-effects model that corrects for the endogenous credit constraint status of the household.

4. Data

Financial services to micro enterprises and low income households in Malawi are provided by a variety and range of private and publicly supported Microfinance Institutions (MFIs) such as NGOs, Companies Limited by Guarantee, Savings and Credit Cooperatives and Commercial Banks including one bank specialized in microfinance. In this paper we use the data collected by the International Food Policy Research Institute (IFPRI) in collaboration with Bunda College in Malawi in 1994 which contains the necessary information needed to identify credit-constrained households as well as those that adopted hybrid maize. The data set is certainly old, which suggests that some conditions in Malawi in 2008 could be different from those in 1994, although to a large extent the poverty levels, the levels of access to financial services by the poor, as well as the structure of the agricultural sector have mostly remained the same. Therefore, aside from explaining the current conditions, our aim is to illustrate how using a well established survey data, one could ultimately measure the effect of credit constraints on technology adoption. The general findings also have significant relevance to current debates about the role of input subsidy programs and the extent of and response to problems of targeting and displacement of unsubsidized purchases by subsidized sales (*e.g.*, Minde *et al.*, 2008).

The IFPRI survey was designed to investigate the effects of access to credit on household welfare. The survey covered households from five districts of Rumphi, Nkhotakota, Dowa, Dedza and Mangochi. The four microcredit programs the survey focused upon included : the Malawi Rural Finance Company (MRFC), a state-owned and nationwide agricultural credit program; Promotion of Micro-Enterprises for Rural Women (PMERW), a microcredit program targeted at women in support of nonfarm income-generating activities; the Malawi Mudzi Fund (MMF), a replica of the Grameen Bank; and the Malawi Union of Savings and Credit Cooperatives (MUSCCO), a union of locally based savings and credit associations. The IFPRI survey focused on these four microfinance institutions as representative of the spectrum of formal credit and savings options available to rural households in Malawi. The sample included 404 households of which half were members of credit programs and the other half were non-members.

The survey questionnaire consisted of several modules including household socio-demographics, crop and livestock production and credit and savings modules as well as Asset modules. The data are available on request from IFPRI.

In the IFPRI survey, respondents were asked whether or not they had tried to borrow from a formal lender in the past 12 months. Those who asked for loans were asked the amount they received and whether they received the full amount demanded. Those that had not attempted to borrow were asked why not. More precisely, the questions were as follows:

– Did any member in your household apply for a loan from a formal institution in the last 12 months? Yes/no
– If household applied, was the loan granted? Yes/no
– If loan was granted was the household granted the same amount the loan as requested? Yes/no
– If household members had not attempted to borrow, give reasons. The choices for the answers were as follows:
  1. I did not need credit
  2. I dislike any borrowing
  3. The loans are too expensive
  4. I would have liked to apply for a loan but did not apply because I felt that lender would not give me a loan because of my age
  5. I would have liked to apply for a loan but did not apply because I felt that lender would not give me a loan because of my health problems
  6. I would have liked to apply for a loan but did not apply because I felt that lender would not give me a loan for other reasons, other than age and health problems
  7. Others

Respondents who chose any of the options 3, 4, 5 and 6 as reasons for not attempting to get a loan from a formal institution (question 2) are categorized as discouraged borrowers. Consistent with the credit literature, these respondents are included with those households that did not receive as much credit as requested from the formal lender and classified as credit constrained. About 43% of the surveyed households were classified as credit constrained.

Table 1 presents household characteristics divided by credit constraint status. Unconstrained households have relatively larger households (6.1 persons) than constrained households (5.4 persons). Results further show that unconstrained households are wealthier with an average household asset value of MK 4168 compared to MK 3293 for the credit constrained (at the time of the survey, 1 US Dollar was worth 44 Malawi Kwachas). Unconstrained households have a much smaller proportion of female-headed households (21%) than households that have some credit binding constraint (30%) suggesting that credit constraints in Malawi could be associated with the gender of household head. Unconstrained households have larger land holdings (2.47 hectares) than constrained households (1.8 hectares). There are no marked differences in terms of age or years of education of the head of household.

Following Feder *et al*. (1985) we define adopters as farmers that reported that they planted first generation hybrid seed as opposed to recycled hybrid seed. About 40% of the sampled households were classified as adopters. Table 2 presents selected characteristics of farmers differentiated by the adoption status of a farmer. 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 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 credit constraints will have a reducing effect on the amount of land allocated to hybrid maize. We also expect farmers close to extension service centers and markets to

Table 1. **Household characteristics by credit constraint status**

`	Unconstrained households (n=233)	Credit constrained households (n=171)	Total (n=404)
Age of head (years)	45.01 (12.19)	45.18 (14.08)	45.13 (13.58)
Years of schooling of head	4.65 (3.46)	4.15 (3.25)	4.28 (3.31)
Sex of head of household (1=male, 0=female)	0.79 (0.41)	0.70 (0.46)	0.72 (0.45)
Population males 15 to 64 years	1.27 (1.03)	1.21 (0.83)	1.22 (0.89)
Population females 15 to 64 years	1.48 (0.77)	1.47 (0.83)	1.47 (0.81)
Household size	6.10 (2.83)	5.41 (2.46)	5.59 (2.58)
Total hectares of household land	2.47 (2.51)	1.87 (1.66)	2.03 (1.93)
Distance to field assistant (kilometers)	2.75 (3.91)	2.04 (3.48)	2.23 (3.61)
Values of household assets (Malawi Kwacha)	4168 (12601)	3293 (6794)	3527 (8723)
Whether received free inputs from government (%)	15	18	16

Source: Own Calculations from Malawi-IFPRI Survey.
Note: Figures in parenthesis are standard deviations.

adopt hybrid maize due to the reduction in transaction costs. 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 larger (5.80 persons) than non-adopters (5.28 persons) at 5% level. It is also observed that adopting households have significantly larger ($P<0.05$) land holdings (2.34 hectares) than non-adopters (1.55 hectares). With regards to wealth, adopters are wealthier with significantly larger asset values (MK 4132) than the non-adopters (MK 2633). In addition, adopters have significantly higher levels of access to formal credit than non-adopting households. A larger proportion of adopters (86%) than non-adopters (50%) rely on agriculture as their primary occupation. Other major sources of livelihoods for non-adopters are self-employment (17%) and wage employment (10%).

5. Results and discussions

Table 3 presents the results on determinants of adoption under credit constraints. Three types of estimations are conducted to illustrate the importance of correcting for endogeneity when assessing the impact of credit constraints. In addition to credit constraints variables, we include other variables theoretically linked to technology adoption. Columns 1 and 2 present estimates of the adoption models estimated through OLS and Tobit regressions respectively, without correcting for the endogenous credit constraint status of a household.

Table 2. **Household characteristics by adoption status**

	Non-adopters (n=243)	Adopters (n=161)	Total (n=404)
Age of head (years)	45.35 (14.22)	44.98(13.17)	45.13 (13.58)
Years of schooling of head of household	3.94 (3.21)	4.51 (3.36)	4.28 (3.31)
Sex of head of household (1=male, 0=female)	0.69 (0.47)	0.75 (0.44)	0.72 (0.45)
Population males 15 to 64 years	1.10 (0.82)	1.31 (0.93)	1.22 (0.89)
Population females 15 to 64 years	1.43 (0.85)	1.50 (0.79)	1.47 (0.81)
Household size	5.28 (2.64)	5.80 (2.52)	5.59 (2.58)
Total hectares of household land (hectares)	1.55(0.88)	2.34 (2.33)	2.03 (1.93)
Distance to extension worker's home (kilometers)	2.70 (3.98)	1.92 (3.30)	2.23 (3.61)
Values of household assets (Malawi Kwacha)	2633.70 (5862.38)	4132.07 (10182.80)	3527.53 (8723.96)
Whether received free inputs from government (%)	15	18	16
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.
Note: Figures in parenthesis are standard deviations.

What is first striking in the results presented in table 3 is the poor performance of the simple OLS and Tobit regressions. The credit constraints variable has an unexpected positive sign and is not significant. The unexpected findings could, however, be attributed to the endogenous credit constraints. Other variables that returned positive and significant signs in the first two models include the land holding size and household wealth. The value of assets which was used as a proxy for household wealth had a positive and significant effect on the amount of land allocated to hybrid maize suggesting that richer households with a higher value of assets (household wealth) allocate more land to hybrid maize cultivation.

The results from the treatment effects model which corrects for the endogenous credit constraints are presented in columns 3 and 4. Column 3 presents estimates of the adoption equation while column 4 presents estimates of the credit constraint equation. One of the parameters of interest, the rho or which measure the correlation between the errors in the credit constraint equation (equation 1) and the reduced-form adoption equation (equation 2) is 0.834 and significantly different from zero (Chi square = 0.0000). These findings suggest that the variable (credit constraint) is endogenous and thus we cannot reject the null hypothesis for no endogeneity of the credit constraint status of a household. Results further indicate that credit constraints have a negative

Table 3. **Determinants of adoption under credit constraints**

Variable	OLS regression	Tobit regression	Treatment regression with correction for endogeneity	
			Adoption	Credit constraints
Credit constraint	0.1109 (0.1458)	0.1171 (0.2232)	– 2.0655*** (0.2291)	
Free input	0.0114 (0.1680)	0.2861 (0.2455)	0.0424 (0.1512)	
Age household head	– 0.0079 (0.0057)	– 0.0113 (0.0089)	– 0.0157** (0.0069)	– 0.0089* (0.0051)
Education head	– 0.0223 (0.0269)	– 0.0512 0.0405	– 0.0413 (0.0330)	– 0.0264 (0.0241)
Gender (1=male)	– 0.0375 (0.1637)	0.1263 (0.2536)	– 0.3010 (0.2010)	
Household size	0.0035 (0.0306)	0.0489 (0.0466)	0.0125 (0.0313)	
Quartile number 2 value of assets	0.4425* (0.2290)	1.0497*** (0.3702)	0.1580 (0.2819)	– 0.2622 (0.2063)
Quartile number 3 value of assets	0.4408* (0.2376)	1.1277*** (0.3702)	0.2130 (0.2910)	– 0.2025 (0.2118)
Quartile number 4 value of assets	0.5095** (0.2434)	1.1510*** (0.3868)	0.4867 (0.2987)	– 0.0406 (0.2226)
Quartile number 5 value of assets	0.7707*** (0.2615)	1.4754*** (0.4088)	0.4023 (0.3211)	– 0.4121* (0.2370)
Total land holding	0.6224*** (0.0400)	0.7182*** (0.0579)	0.6340*** (0.0491)	0.0716 (0.0511)
Tobacco grower (yes-1, no=0	– .079694 (0.19109)	0.06034 0.29101	– 0.2990 (0.184)	
Distance to the extension worker	0.0063 (0.0232)	0.0090 (0.0372)	– 0.0027 (0.0220)	
Nkhota	– 0.4950* (0.2717)	– 1.0683** (0.4191)	– 0.2912 (0.3302)	0.1679 (0.3417)
Rumphi	– 0.4634 (0.2834)	– 0.6453 (0.4260)	– 0.4454 (0.3447)	– 0.1955 (0.3457)
Dedza	– 0.5575* (0.2437)	– 1.1954*** (0.3815)	– 0.6879** (0.2971)	– 0.1387 (0.2633)
Constant	0.2223 (0.4103)	– 1.0922* (0.6489)	1.8687*** (0.5107)	0.6665* (0.3671)
Number of females (15-64 years)				0.1496** (0.0699)
Member of MRFC				– 0.4933*** (0.1420)
Member of MUSCO				– 0.8515*** (0.2425)

Table 3. **Determinants of adoption under credit constraints** *(continued)*

/Athrho [a]			1.1828*** (0.1240)	
/lnsigma		1.9744 (0.0956)	0.5500*** (0.0522)	
Rho			0.8345*** (0.0369)	
Sigma			1.7482 (0.0897)	
No. of obs	404	404	404	404
LR test of indep. Eqns. (rho = 0): chi2(1) = 39.93 Prob > chi2 = 0.0000				

Source: Own calculation from RDD/IFPRI Rural Finance Survey.
Notes: * ,**, ***: Significance at 10%, 5%, and 1% level.
Figures in parenthesis are standard errors.
[a] lnsigma and Athrho are transformations of sigma and rho that are used in` the estimation process.

and significant effect on the amount of land allocated to hybrid maize. These findings indicate that being credit constrained reduces the amount of land cultivated under hybrid maize, which is consistent with *a priori* expectations that due to credit constraints farmers are unable to purchase hybrid seed.

Other than credit constraints, a number of other variables returned significant coefficients. The age of the household head has a negative and significant effect on the adoption of hybrid maize. 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 tend to stick to their old production techniques and are usually less willing to accept change. In addition young people are associated with a higher risk-taking behavior than the elderly.

The land holding size returned a positive and significant coefficient indicating that households with larger land holdings allocated more land to hybrid maize. The result is consistent with a priori expectations in that it is widely hypothesized that the adoption of innovation tends to take place earlier on larger farms than on smaller farms. Consistent with this notion, Just *et al.* (1980) point out that given the uncertainty, and fixed transaction and information costs associated with innovation, there may be a critical lower limit on farm size that prevents smaller farms from adopting. A more plausible argument that relates to the situation in Malawi could be related to what Feder *et al.* (1985) refer to as the problem of disentangling farm size from other factors hypothesized to influence technology adoption. They argue that farm size may be surrogate for other factors such as wealth, risk preferences, and access to information which also positively influence adoption.

The size of a household returned a positive but insignificant sign. The positive effect of household size on 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. However the insignificant effect can be

explained by the fact that the extent of adoption of hybrid maize (amount of land cultivated) is more likely to depend on the ability of the household to finance the purchase of inputs such as seed and fertilizer required for the cultivation of hybrid maize, than the abundant household labor. 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.

Free inputs have a positive but insignificant effect on hybrid maize implying that receiving free inputs encourages farmers to grow some hybrid maize but does not significantly increase the area of land allocated to hybrid maize. This can be explained as the amount of free inputs, distributed in form of fertilizer and seed, are usually the same across households and that they are usually only enough for the cultivation of about 0.25 acres. Thus although we expect free input to be significant in influencing the probability of growing hybrid maize, it is not important in influencing the amount of land under hybrid cultivation. The growing of tobacco had a reducing effect on the amount of land allocated to hybrid maize but its effect is not significant.

The results from a credit constraints equation (column 4) indicate that the value of household assets has a reducing effect on the likelihood of reporting credit constraints. Results indicate that households in the fifth quartile of the value of household non-agricultural assets are less likely to report credit constraints. The findings suggest that wealthier households in the third, fourth and fifth quartiles are less likely to face credit constraints. The probability of reporting credit constraints declines by about 5% in the fifth wealth category. This is consistent with prior expectations in that wealthier households are more likely able to self-finance which reduces their need for loans. The findings are also consistent with an observation made by Zeldes (1989) and Hayashi (1985) in which they report that constrained households are likely to have little wealth. The membership in credit programs also has a reducing effect on the likelihood of facing credit constraints suggesting that membership in credit programs allows members to meet their financial needs.

6. Conclusions

This study has examined the impact of credit constraints on the adoption of hybrid maize and demonstrated the importance of correcting for endogeneity when assessing the impact of credit constraints on technology adoption. This is done by comparing outcomes from OLS and the Tobit regressions with those from the treatment effects model with correction for endogenous credit constraints.

Results reveal that once corrected for endogeneity, credit constraints have a negative effect on the adoption of hybrid maize. Results also indicate that factors that are seen to affect adoption under models that do not address endogeneity are different from those that influence adoption when credit constraints are treated as endogenous to the model. Results further show that the amount of land allocated to hybrid maize increases with household land size. The fact that credit constraints have higher and negative impact on the cultivation of hybrid maize suggests that there is scope for increasing the cultivation of hybrid maize by increasing access to credit by credit-constrained households. The negative and significant impact of age of the farmer on

the adoption of hybrid maize suggests that credit should be targeted at younger farmers that are credit constrained to enhance their cultivation of hybrid maize. Our results also indicate that free input distribution has a positive but insignificant effect on the amount of land allocated to hybrid implying that small quantities of free seed distributed to liquidity constrained households may be too small for making a significant impact on the size of land under hybrid cultivation.

References

Carr S.J. (1997) A green revolution frustrated: Lessons from the Malawi experience, *African Crop Science Journal* 5(1), 93-98 *(www.bioline.org.br)*.

Conroy A. (1992) The economics of smallholder maize production in Malawi with reference to hybrid seed and fertilizer, unpublished PhD thesis, Manchester University.

Cornejo J., McBride W. (2002) Adoption of bioengineered crops, Agricultural Economics Report n° 810, Washington DC, USA.

Cragg J. (1971) Some statistical models for limited dependent variables with application to the demand for durable goods, *Econometrica* 39, 829-844.

CYMMYT (1998) Maize technology in Malawi: A green revolution in the making?, accessed at *http://www.cymmyt.cgiar.org/Research/Economics/Revisar/htm/maizeimp.htm.*

Diagne A., Demont M. (2007) Taking a new look at empirical models of adoption: Average treatment effect estimation of adoption rate and its determinants, *Agricultural Economics* 37, 2001-2010.

Diagne A., Zeller M. (2001) Access to credit and its impact on welfare in Malawi, Research report n° 116, International Food Policy Research Institute, Washington DC, USA.

Diagne A., Simtowe F., Chimombo W. and Mataya C. (2000a) Design and sustainability issues of rural credit and savings programs for the poor in Malawi: An action-oriented research project, International Food Policy Research Institute (IFPRI), Washington DC, USA.

Diagne A., Zeller M. and Sharma M. (2000b) Empirical measurements of households' access to credit and credit constraints in developing countries: Methodological issues and evidence, Discussion paper n° 90, Food Consumption and Nutrition Division, International Food Policy Research Institute (IFPRI), Washington DC, USA.

Eicher C.K. (1995) Zimbabwe's maize-based green revolution: Preconditions for replication, *World Development* 23, 805-818.

Eswaran M., Kotwal A. (1990) Implications of credit constraints for risk behavior, *Oxford Economic Papers, New Series*, 42 (2), 473-482.

Feder G., Umali D.L. (1993) The adoption of agricultural innovations: A review, *Technological Forecasting and Social Change* 43, 215-239.

Feder G., Just R.E. and Zilberman D. (1985) Adoption of agricultural innovations in Developing Countries: A survey, *Economic Development and Cultural Change* 33 (2).

Gilligan D., Harrower S. and Quisumbing A. (2005) How accurate are reports of credit constraints? Reconciling theory with respondents`claims in Bukidnon, IFPRI-Philippines, Wahington DC, USA.

Gough A.E., Hildebrand P.E. and Gladwin C.H. (2002) Vouchers versus grants: Evidence from Malawi's starter pack program, *African Studies Quarterly* 6 (1-2).

Government of Malawi (2004) Agriculture statistics crop production estimates, Ministry of Agriculture and Livestock Development, Malawi.

Green W.H. (2000) *Econometric Analysis*, 5th ed, Upper Saddle River NJ, Prentice Hall.

Hassan R.M., Murithi F. and Kamau G. (1998) Determinants of fertilizer use and the gap between farmers' yields and potential yields in Kenya, *in: Kenya in Maize Technology Development and Transfer: A GIS Application for Research Planning in Kenya*, Hassan R.M. (ed.), Wallingford, United Kingdom, CABI Publishing.

Hayashi F. (1985) The effect of liquidity constraints on consumption: A cross-sectional analysis, *Quarterly Journal of Economics* 100 (1), 183-206.

Janvry A. (de), Key N. and Sadoulet E. (1997) Agricultural and rural development policy in Latin America. New directions and new challenges, *FAO Agricultural Policy and Economic Development Series 2,* Rome, Italy.

Jappelli T. (1990) Who is credit constrained in the US economy? *Quarterly Journal of Economics* 105 (1), 219-234.

Jones R.B., Heisey P.W. (1994) An agronomic and economic analysis of the results from the MoALD/UNDP/FAO Fertilizer Demonstration Programme 1989-93, Lilongwe, Malawi, Ministry of Agriculture, United Nations Development Programme, Food and Agricultural Organization, Mimeo.

Just R.E., Zilberman D. and Rausser G.C. (1980) A putty-clay approach to the distributional effects of new technology under risk, *in: Operations Research in Agriculture and Water Resources,* Yaron D., Tapiero C.S. (eds), New York, North-Holland, 97-112.

Karanja D.D. (1993) An economic and institutional analysis of maize research in Kenya, MSU International Development Paper 15, Department of Agricultural Economics, Michigan State University, East Lansing, Michigan.

Minde I., Jayne T.S., Crawford E., Ariga J. and Govereh J. (2008) Fertilizer subsidies and sustainable agricultural growth in Africa: Current issues and empirical evidence from Malawi, Zambia, and Kenya, Paper prepared for the Regional Strategic Agricultural Knowledge Support System (Re-SAKSS) for Southern Africa, Food Security Group, Michigan State University.

Sawada Y., Kubo K., Fuwa N., Ito S. and Kurosaki T. (2006) On the mother and child labour nexus under credit constraints: Findings from rural India, *The Developing Economies* XLIV-4.

Simtowe F., Mduma J., Phiri M.A.R., Thomas A. and Zeller M. (2006) Can risk-aversion towards fertilizer explain part of the non-adoption puzzle for hybrid maize? Empirical evidence from Malawi, *Journal of Applied Sciences* 6 (7), 1490-1498 *(http://ansijournals.com/jas/2006/1490-1498.pdf)*.

Smale M. (1995) Maize is life: Malawi's delayed green revolution, *World Development* 23, 819-831.

Smale M., Phiri A. (eds) (1998) Institutional change and discontinuities in farmers' use of hybrid maize seed and fertilizer in Malawi: Findings from the 1996-97, CIMMYT/MoALD Survey, Economics working paper 98-01, Mexico DF.

World Bank (1996) Malawi human resources and poverty, Report n° 15437.

Zeldes S. (1989) Consumption and liquidity constraints: An empirical investigation, *Journal of Political Economy* XCVII, 305-346.

Zeller M., Diagne A. and Mataya C. (1998) Market access by smallholder farmers in Malawi: Implications for technology adoption, agricultural productivity, and crop income, *Agricultural Economics* 19 (2), 219-229.

Zeller M., Sharma M., Henry C. and Lapenu C. (2006) An operational method for assessing the poverty outreach performance of development policies in Africa, Asia and Latin America, *World Development* 34 (3), 446-464.

ANNEX

Table A1. **Descriptive statistics of regression variables**

Variables	Mean	Std. deviation	Minimum	Maximum
Dependent Variables				
Land cultivated under hybrid maize (hectares)	1.260087	1.884684	0	25
Whether credit constrained (1=yes, 0=no)	0.4233	0.4947		
Independent variables				
Whether credit constrained (1=yes, 0=no)	0.4233	0.4947	0	1
Age of household head (years)	45.1312	13.5840	20	86
Years of schooling of head	4.2822	3.3102	0	12
Gender of household head (1=male)	0.7228	0.4482	0	1
Household size	5.5941	2.5775	1	16
Number of adult males in a household (15-64 yrs)	1.2249	0.8914	0	6
Population of adult females	1.4706	0.8146	0	5
Land holding size (ha)	2.0196	1.9208	0	21.40
Value of assets owned (MK)	3527.52	8723.95	100	126920
Whether receive free inputs (1=yes)	0.160891	0.4300	0	5
Distance to the extension office	2.2334	3.6074	0	15
Members in PMEW program	0.4400	0.4970	0	1
Members in MRFC program	0.2376	0.4262	0	1
Members in Mudzi program	0.0693	0.2543	0	1
Members in MUSCO program	0.0718	0.2584	0	1
Mangochi	0.2450	0.43065	0	1
Nkhota kota	0.1757	0.3810	0	1
Rumphi	0.1905	0.3932	0	1
Dedza	0.2524	0.4349	0	1

Source: Own calculation from RDD/IFPRI Rural Finance Survey.