Can Risk-aversion towards fertilizer explain part of the non-adoption puzzle for hybrid maize? Empirical evidence from Malawi

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Abstract

This study investigates the linkage between attitudes towards risk and adoption. We empirically examine the relative risk premium related to fertilizer-use among 404 farmers from Malawi and examine the relationship between risk aversion on fertilizer-use and the adoption of hybrid maize. Results show that Malawian farmers exhibit absolute Arrow-Pratt risk aversion towards the use of fertilizer. The findings also reveal that risk aversion towards the use of fertilizer is strongly associated with low intensity of hybrid maize adoption and that other than the safety net programs, human and financial capital variables such as age, household size, land size and off-farm income can be helpful in explaining the non-adoption puzzle. While safety net programs such as the free input distribution increase the likelihood of adoption, they are associated with low adoption intensity for hybrid maize. A key lesson is that when considering promoting a technology, it is important to assess the profit distribution associated with the use of complementary inputs and its implications for risk preference among technology users in order to avoid formulating misguiding policies.

Keywords: Adoption, hybrid maize, fertilizer, risk-aversion, Malawi.

1.0 Introduction

There is a wide acceptance that technological change is crucial in achieving sustained agricultural productivity growth. Increased adoption of improved technologies remains the key to achieving food security in most parts of the world, and more so in the Sub-Saharan Africa region where agriculture is mainly characterized by low use of improved technology and low productivity. For the last two decades Malawi's agricultural productivity growth remained lower (1.9 percent per year) than the rate of population growth (2.1 percent per year). This trend has had serious implications on achieving national and household food security. Low adoption of improved varieties coupled with low input use patters and persistent droughts are blamed for this trend (Government of Malawi, 2003).

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

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for the past 4 decades[2], emphasized the production of hybrid maize, a capital intensive and high yielding technology as a substitute to the local maize varieties. The provision of micro-credit and free inputs in form of fertilizer and seed to farmers are some the strategies that the government of Malawi has been executing to promote the adoption of hybrid maize (Zeller, et al 1997). Both, credit provision and free input distribution are expected to promote the adoption of hybrid maize through the relaxation of the liquidity constraint. Despite such concerted efforts by the government, and more recently Non-governmental Organizations (NGOs), adoption of hybrid maize remains low. By 2003, more than half of the total maize land was allocated to local varieties (GOM. 2004).

A substantial amount of adoption literature has reported on the determinants of adoption and a good deal of it showing that poor people are risk-averse and that their production decisions are characterized by a high degree of uncertainty. Feder and Umali (1990) and Cornejo et, al (2002) review factors that affect technology adoption, and they highlight risk preference as one of the key determinants of adoption of most agricultural innovations. Although the issue of risk has been mentioned in such literature, the link between risk-aversion and adoption has not been adequately addressed. One notable exception is an attempt by Koundouri et.al, (2006), who motivated by the empirical evidence that most farmers are risk-averse and the general notion that agricultural technological innovations are perceived to be more risky than traditional technologies, assess the role of risk preferences on the adoption of irrigation technologies among 265 farms located in Crete, Greece. Nevertheless, their analysis, simply looks at the decision to adopt, and does not look at the extent of adoption. Analyzing the adoption decision separately from the intensity of adoption is important because factors that affect the decision to adopt may be different from those influencing the intensity of adoption.

Following Smale et. al, (1995) farmers adoption of hybrid maize seed in Malawi is characterized by several choices, one being whether to adopt only seed, only fertilizer or both. Other choices are related to the extent of adoption (land allocated to the technology) and the intensity of adoption (level of technology per hectare). Fertilizer considerations are important when analyzing maize adoption in Malawi because hybrid maize has to be accompanied by fertilizer in order to realize maximum yields.

Among the several models provided by micro economic theory relating to adoption are the safety first models. The models assume that farmers that are constrained by the prospect of failing to attain their subsistence needs choose crop allocations that diverge from those associated with profit maximization (Smale et. al (1995). A related model is the portfolio selection model which states that risk-averse farmers who maximize the expected utility of income as opposed to maximizing the expected profit, can increase overall mean returns or reduce overall variance of returns by choosing a combination of seed varieties. In the case of Malawian farmers, although adopting hybrid maize is plausible, in times of drought or water stress, the yields are much lower than those of the traditional varieties. In addition it is widely believed that in the absence of fertilizer, local maize performs much better than hybrid maize. Morris Michael (1998) notes that fertilizer considerations are particularly crucial when deciding to grow maize because, of all the inputs in agriculture, none has the ability to affect productivity as much as seed. Adoption of hybrid maize, therefore, has direct implications on the use of fertilizer.

A study on risk preference and adoption has significant policy relevance. Risk considerations are important in the analysis of the agricultural sector as there exists a

[2] Since independence Malawi's food policy has emphasized self sufficiency in Maize

number of possible cases where intelligent policy formulation should consider not only the marginal contribution of input use to the mean of output, but also the marginal reduction in the variance of output (Koundouri et al, 2006). Ignoring the impact of risk in an adoption study can provide misleading guidance to policy makers. This study is motivated by a hypothesis that other than access to credit, risk preferences related to variance of profit and attitude to downside-risk may be responsible for the low adoption of such technologies. Specifically, we hypothesize that that farmers that exercise risk-aversion towards fertilizer-use are less likely to adopt hybrid maize. The general objective of this paper is, therefore, to assess the determinants of the adoption of hybrid maize among farmers that vary in their risk preferences towards the use of fertilizer.

In order to estimate risk preferences, we use a theoretical framework that conceptualizes adoption as a decision process involving information acquisition by farmers who vary in their risk preferences and in their access to credit. We integrate the microeconomic foundations used to analyze production uncertainty at the farm level with the traditional technological adoption models. We adopt Antle's (1987) moments based approach to evaluate individual risk preferences with regards to the use of fertilizer, and then later incorporated the risk-preference as one of the explanatory variables in the adoption model. The analysis on adoption is done using the Heckman procedure. In the first stage we estimate the probability of adoption using the logit model. The second stage on the extent of adoption is estimated using the Generalized Linear Model.

The rest of the paper is arranged as follows: in section two we present a review of literature on adoption. In section three we present the underlying model of farmer's behavior under risk[3] and discuss implications of risk aversion for the adoption of hybrid maize variety. The data used for the estimation is from Malawi and described in section four. In the applied econometric analysis of section five, we derive farmer-specific risk attitudes characteristics (absolute Arrow-Pratt and down-side risk aversion coefficients and risk premium) and we analyze the impact of risk preference on the adoption of technology. The empirical estimation of both, risk preferences and impacts on adoption are discussed. Section six concludes with some policy implications.

2.0 Literature on Adoption of improved maize technologies

A number of adoption studies report that technology adoption is linked to farmer resource endowment in terms of human, physical and financial capital, risk preferences, location factors and the characteristics of the technology itself. Among the key endowment factors is the farm size. It is generally hypothesized that larger farmers tend to adopt new technologies faster than smaller farmers. Feder et.al (1985) point that considering the uncertainty and the fixed transaction and information cost associated with innovations, there may be a critical lower limit on farm size that prevents smaller farmers from adopting. As the costs increase, the critical size also increases. Innovations with large transactional costs are therefore less likely to be adopted by smaller farmers. Ferder et, al (1985) however point out that it is difficult to isolate the impact of farm size on technology adoption from others in the sense that farm size may for example be related to other factors such as credit access, wealth and risk preferences.

[3] Adopted from Koundouru, et al, (2005)

Literature on studies devoted to production decisions by peasants in the developing countries provide rich incites about the link between adoption and risk preference. Work on risk-aversion dates as far back as 1971 when Sandmo established that a risk-averse firm facing output risk will produce less output than a risk neutral firm. The general notion in this literature is that farmers tend to use fewer inputs than would have done if they maximized expected profit due to risk aversion. There is wide acceptance that farmers only partially adopt or do not adopt at all even when the new technologies provide higher returns to land and labor than the traditional technologies (Yesuf, 2003). Studies on risk-aversion, therefore, have played an important role in understanding how farmers make production decisions.

de Janvry (2000), reports that households can reduce exposure to consumption risk through risk management (interventions which are ex-ante relative to income realizations) and through risk coping (ex-post relative to income), and there is hence a tradeoff between the two. Since risk management has an opportunity cost on expected income, improved access to risk coping instruments may allow households to take higher risks in production and achieve higher expected incomes (Binswanger and Rosenzweig, 1993; Morduch, 1992). Access to risk coping instruments such as flexible credit, by the poor has been used as a way of raising expected incomes.

Using IFPRI data from Malawi, Zeller et, al (1997) investigates factors that affect the extent of adoption of maize and tobacco. They observe that adoption of agricultural innovations is mainly influenced by human capital, labor availability, farm size and access to commodity markets. The study notes that, although yields for local maize were lower by 49 percent compared to hybrid maize, the local maize varieties were grown by half of the households. The main reason was that hybrid maize exhibited higher risks than local maize. The study points out that risk exposure and capacity to bear risk and credit constraints are key factors that influence adoption. The implications from this study are that households with lower risk bearing ability are likely to prefer local maize to hybrid maize. Nevertheless, the study does not further analyze how farmers that vary in their risk preferences towards fertilizer-use respond to the adoption of hybrid maize. The study notes that the variability of yield and profit (variance) influence farmer adoption behavior. Although variability considerations are important, they insufficient to explain farmer behavior unless complemented by the attitude towards downside risk as well. Smale and Heisley (1994) assesses the factors affecting the adoption of hybrid maize and fertilizer. Although they mention the role of risk in adoption, they do not empirically measure risk preferences among farmers and therefore conclusions about risk and adoption tend to lack evidence.

3.0 Theoretical and Empirical Framework

3.1. Framework for risk preference

Risky returns occur in the context of crop production because either the yields or prices or both are uncertain (Dillon, 1977). Often, uncertainties arise from the influence of the uncontrolled variables whose levels are unknown. If the probability of distribution of a return relative to the uncontrolled variables can only be specified conditional on controlled variables, the choice and level of controlled variables will influence the distribution of the return. Therefore in such a case, the choice and levels of controlled inputs should allow for risk effects. An individual is said to be risk neutral if the utility of the expected value is equal to the expected utility. In such cases the individual is said to have a linear utility function. An individual is said to be risk averse if his or her NM utility function is strictly concave, thus if the utility of the expected value is greater than the expected utility. Similarly an individual is said to be a risk lover if his or her NM utility function is strictly convex (Takayama, 1993).

Hybrid maize performs better when supplemented with the use of fertilizer and therefore to maximize returns, its adoption has to be accompanied by costly inorganic fertilizers and seed. Malawi is highly dependent of rain-fed agriculture such that more than 80 percent of total maize production is rain-fed. However, for more than a decade now, Malawi has been experiencing persistent rainfall uncertainties. Although hybrid maize is superior in terms of yield, to local maize, in the event of dry spells, local maize produces higher yields than hybrid maize. This also implies high risk for fertilizer-use on hybrid maize. Farmers that are risk-averse towards fertilizer may therefore choose not to adopt hybrid maize despite its potential yield. In the analysis that follows, we try to take into account the risk-preference of each farmer associated with the use of fertilizer and find out how it affects adoption of hybrid maize.

We consider a risk-averse farmer who produces a single crop with output *q*. Let *p* denote the output price, *f*(.) is the production function, f is the fertilizer input , x_0 is the vector of other inputs and *r* is the vector of input prices.

Applying fertilizer to maize (*f*) is considered to be an important input for production to occur. Assuming that inputs are chosen to maximize the expected utility of profit EU(π). The total profit of a farm activity is:

$$\pi = \sum_{i=1}^{n} pf(f,.x_0) - r_f f - r' x_0 , \qquad [1]$$

The von Neumann-Morgenstern utility function U(π) represents risk preferences of a farmer. The farmer's utility maximization problem is:

$$\underset{x_0 f}{Max}\, EU(\pi) = \underset{x_0 f}{Max} \sum_{i=1}^{n} pf(f, x_0) - r_f f - r' x_0 , \qquad [2]$$

Allowing for risk aversion and assuming the cost of private risk bearing to be R, then the farmer's problem is to maximize the certainty equivalent of profit given as:

$$EU(\pi) = U[E(\pi) - R], \qquad [3]$$

where, R is the risk premium which measures the maximum amount that the risk averse individual is willing to pay to have the sure return rather than the expected return from the uncertain prospect (Takayama,1993). It is assumed that R>0, ie that the farmer prefers a risk-less world. The risk exposure also depends on inputs, f, x_0, thus R(f, x_0). From equation (3), maximizing expected utility is equivalent to maximizing the certainty equivalent,

$$E[\pi(f, x_0] - R(f, x_0), \qquad [4]$$

Assuming that the risk R is represented by a random variable ξ with distribution *G*(.), then the farmer maximization problem of expected utility of profit without considering any constraint can be written as:

$$\underset{x_0 f}{Max}\left[E(U(\pi)\right] = \underset{x_0 f}{Max}\int U(pf((\varepsilon, f, x_0) - r_f f - r'x_0)dG(\varepsilon)\,, \qquad [5]$$

where U(.) is the *von Neumann-Morgenstern* utility function. The first order condition associated with use of fertilizer *f* defines the marginal risk premium with respect to fertilizer.

$$\partial R / \partial f \;=\; p \times E\left({(\partial f(\varepsilon, f, x_0)} \big/ {\partial f} \right) - r_f\,, \qquad [6]$$

The first order condition for fertilizer can be written as follows:

$$E\left[r_f U'\right] = E\left\{P \frac{\partial f(\varepsilon, f, x_0)}{\partial f} U'\right\} \qquad [7]$$

$$\frac{r_f}{p} = E\left[\frac{\partial f(\varepsilon, f, x_0)}{\partial f}\right] + \frac{\text{cov}(U';\partial f(\varepsilon, f, x_0)/\partial f)}{E(U')}\,,$$

where U´ is a change in the utility of profit as a result of a change in profit $\left({\partial U(\pi)} \big/ {\partial \pi} \right)$.

For a risk neutral farmer the ratio of the two prices in equation 7 is equal to the expected marginal product of fertilizer input, which is equal to the first term in the right hand –side of equation 7. The second term in the right hand-side of equation 7 measures deviations from the risk neutrality case and it is different from zero when a farmer is risk-averse. The term is proportional and has an opposite sign to the marginal risk premium with respect to fertilizer specified in equation 6.

A farmer only adopts hybrid maize if the expected utility with adoption is greater than the expected utility without adoption. The expected utility under adoption is:

$$E\left[U(\pi^a)\right] = \int \left[U(pf(\varepsilon, f^a, x_0^a) - r_f^a f^a - r' x_0^a - re\right] \partial G(\varepsilon) \qquad [9]$$

Where, *re* is the cost of extra inputs that accompany the use of hybrid seed since it has to be bought at a higher price.

A non-adoption scenario can be presented as follows:

$$E\left[U(\pi^n)\right] = \int \left[U(pf(\varepsilon, f^n, x_0^n) - r_f^n f^n - r' x_0^n\right] \partial G(\varepsilon) \qquad [10]$$

A farmer adopts an improved variety only if the expected utility under adoption is greater than the expected utility under non-adoption, thus

$$E\left[U(\Pi^a)\right] > E\left[U(\Pi^n)\right] \qquad [11]$$

3.2 Econometric estimation of risk attitudes

Antle (1987) proposes a moment based approach to estimate risk-attitude parameters of a population of producer. We assume that a farmer maximizes a function of moments of the profit distribution. We firstly estimate the risk-premium of each farmer associated with the use of fertilizer which is later incorporated in the adoption models that are specified in the later stages. Following this approach, the farmer's program becomes:

$$\text{Max } E[U(\pi)] = [f(\mu_1(X), \mu_2(X), \ldots \mu_m(X)] \qquad [12]$$

where μ_j, j=1,2……, m is the m^{th} moment of profit.

The first order condition of the program is approximated by the following Taylor expansion, in matrix form. Following the Taylor expansion which is not specified here, one can derive the marginal contribution of input j to the expected profit as follows:

$$\frac{\partial u_1(X)}{\partial X_j} = \theta_{1j} + \theta_{2j}\frac{\partial u_2(X)}{\partial X_j} + \theta_{3j}\frac{\partial u_3(X)}{\partial X_j} + \ldots\ldots + \theta_{mj}\frac{\partial u_m(X)}{\partial X_j} + u_j \qquad [13]$$

where $\theta_{2j} = -\alpha_{2j} \times (1/2!), \theta_{3j} = -\alpha_{3j} \times (1/3!), \theta_{mj} \times (1/m!)$ and u_j is the usual econometric error term. A nice feature of this model is that the parameters $\theta_{2j} and \theta_{3j}$ are directly interpretable as Arrow-Pratt and down-side risk aversion coefficients respectively (Koundouri et, al. 2006).

The Arrow-Pratt (AP) absolute risk aversion coefficient is defined by:

$$AP_j = -\frac{E(U''(\pi))}{EU'(\pi)} \cong -\frac{\partial F(X)/\partial\mu_2(X)}{\partial F(X)/\partial\mu_1(X)} = 2\theta_{2j} \qquad [14]$$

A positive AP coefficient means that the farmer is risk –averse. Down –side (DS) risk aversion is measured by

$$DS_j = \frac{E(U''(\pi))}{EU'(\pi)} \cong \frac{\partial F(X)/\partial\mu_3(X)}{\partial F(X)/\partial\mu_1(X)} = -6\theta_{3j} \qquad [15]$$

A positive DS coefficient means that the farmer is averse to down-side risk (Groom et al., 2006). Usually the higher moments have less influence on the dependent variable, as such this analysis will concentrate of the first three moments (i.e mean, variance and skewness) The risk premium is computed by:

$$RP = \mu_2\frac{AP_j}{2} - \mu_3\frac{DS_j}{6} \text{ for each } j, \qquad [16]$$

where μ_2 and μ_3 are , respectively a measure of the second- and third-order moments of the distribution. The risk premium derived from the process is used as an explanatory variable in the adoption model.

The empirical estimation of the analysis of these moments can be conducted as follows:

$$\pi_1 = f_1(x_i \ldots\ldots x_j, \beta_1) + v_{1\Pi} \text{ for the expected value of profit, } \mu_1 \qquad [17]$$

where $v_{1\Pi}$ is an error term distributed with mean zero, E($v_{1\Pi}$)=0. Let $\beta_1{}^{LS}$ be the least square estimator of β_1 in (17) giving the least squares residual $v_{1\Pi}{}^{LS} = \pi_1 - f_1\left(x_{i.}.....x_j, \beta_1{}^{LS}\right)$. [18]

Consider the following model specification

$$\left(v_{1\Pi}{}^{LS}\right)^2 = f_2\left(xi........xn, \beta_2\right) + v_{2\Pi}, \quad [19]$$

for the expected value of the variance of profit (μ_2).

The least square estimation of (19) gives $\beta_2{}^e$, a consistent estimator of β_2 (Antle, 1983). It follows that $f_2\left(xi........xn, \beta_2{}^e\right)$ is a consistent estimator of the variance of profit, $Var(v_{1\Pi})$. Using the same procedure you can estimate skewness (μ_3).

Following Groom et al (2006) we estimate derivatives to each moment with respect to fertilizer cost. A 2 SLS equation[4] of the estimated derivative of the expected profit is finally fitted on derivatives of higher moments for the seed cost. The parameters associated with the second and third moments, denoted by ϑ_{2j} and ϑ_{3j}, respectively are used as proxies for the Arrow-Pratt (AP) and the down side (DS) risk aversion measures as stated above.

3.3 Determinants of Adoption

We analyze the impact of risk attitude and other relevant variables on the adoption of hybrid maize. A relative risk premium, which is a measure of the proportion of profit that each farmer would be willing to pay in order to avoid the risk associated with using fertilizer, is computed using the empirical framework outlined in section 3.2. The computed relative risk premium is included as one of the explanatory variables in the adoption model. We follow a two step Heckman procedure in estimating the determinants of adoption. In the first step we estimate the likelihood of adoption using the Logit model. The decision to adopt hybrid maize is assumed to be determined by a latent variable y* such that

$$y = y^* \quad \text{if } y_i^* > 0$$
$$= 0 \quad \text{otherwise}$$

y_i^* can be expressed in the following functional form:

$$y_i^* = \beta_i X_i + \beta_k \delta + \mu_i$$

where X is a vector of farm household characteristics, which, it is hypothesized that they affect the adoption decision, δ is a variable associated with risk preference, β_i is a vector of coefficients for variables associated with adoption, and β_k is the coefficient associated with the risk preference variable.

In the second step we estimate determinants of the extent of adoption using the proportion of land allocated to hybrid maize as a measure of the extent of adoption only for those that reported growing hybrid maize. Heckman (1979) indicates that in such a case, there is a selection bias because information on part of the sample is missing. On

[4] We use rainfall intensity, rainfall variation, the value of agricultural assets and soil quality as instruments

the other hand including all respondents and running a regression with land allocated to hybrid maize as a dependent variable will lead to biased estimates. To correct for this bias, Heckman recommends the estimation of the likelihood equation and the intensity equation separately. From the likelihood of participation equation, an Inverse Mills ratio (see Smits (2003), for a detailed procedure) is computed from the predicted probabilities. The inverse Mill ratio is later included as one of the explanatory variables in the intensity equation. Considering that the dependent variable in this stage is a ratio with a minimum of zero and maximum of one, OLS estimation would lead to biased estimates. The equation is therefore estimated using the Generalized Linear Model (GLM).

4.0 Data and sampling

Data is drawn from the Malawi Rural Financial Markets and Household Food Security Survey, 1995´, conducted by the International Food Policy Research Institute (IFPRI) and the Department of Rural Development (DRP) of the University of Malawi. The survey covered 404 households selected via stratified random sampling method, from the three regions and from 5 districts. The survey districts are Rumphi in the Northern region, Nkhotakota, Dowa and Dedza in the central region, and Mangochi in the southern region. The survey data is categorized in seven modules, however only 3 modules were of relevance to this study and they included, household demographics, crop and livestock and credit and savings modules. Descriptive statistics for variables included in this analysis disaggregated by the adoption status are presented in Table 1. Adopters are households that reported that they grew hybrid maize during the 1995 growing season when the survey was conducted.

There are no marked differences in terms gender, age and education of household head between adopters and non-adopters. However, adopting households are significantly (at 5 percent level) larger (4.9) than non adopters (4.3). It is also observed that adopting households have significantly larger ($P<0.05$) land holdings (1.8hactares) than non adopters (1.5hectares). 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 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%).

5.0 Results and discussion

5.1 Risk attitudes towards the use of fertilizer

Table 2 shows risk attitude statistics towards the use of fertilizer as an input in the production of maize. The results are in compliance with the expectation of risk aversion behavior among smallholder farmers towards fertilizer-use. First the constant is insignificant which implies fertilizer is efficiently used by the farmers and that farmers have a profit maximizing behavior. A negative and significant constant implies that farmers are underutilizing the input under consideration, while a positive coefficient signifies overuse of the input. By definition we should not observe a significant constant term in the model linking the derivatives of moments with respect to each input (Groom et al. 2006). The parameter associated with Arrow –Pratt (θ_2) is positive and significant which indicates that farmers are averse towards the use of larger quantities of fertilizer. A simultaneous adoption of hybrid maize and fertilizer is crucial for the productivity of hybrid maize. Risk aversion on fertilizer-use can have serious implications on the adoption of hybrid maize. The parameter associated with downside-risk aversion, (θ_3), which measures the cumulative probability of getting lower returns, has the expected sign and is significant which implies that farmers are also averse to down-side risk associated with the use of fertilizer.

5.2.1 Determinants of the decision to adopt

Table 3 presents first stage logit estimates of the determinants of likelihood of adoption. The model chi-square which measures the goodness of fit of the model is significant at 1 percent level, signifying a good fit. Other than location dummies (Mangochi, Nkotakota, Rumphi and Dedza), a number of variables included in the model are significant. The amount of off-farm income is positive and significant at $p<0.01$, implying that it increases the probability of adopting hybrid maize. The finding is in line with our expectation because off-farm income is crucial in the financing of the purchase of seasonal inputs that accompany 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. The coefficient for age of the household head is negative and significant ($p<0.01$) implying that older household heads are unlikely to grow hybrid maize. Among the several reasons that could explain this scenario is 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.

Total land holding size of a household is positive and significant at 1 percent. This implies that households with large holdings have a higher probability of adopting hybrid maize than those with smaller holdings. There are two possible explanations to this. First, households with larger portions of land have access to a wider range of financial services in both the formal and informal sectors and therefore more likely to have the financial capacity to purchase inputs required for the adoption of maize.
Second, households with more land are also likely to be wealthier, with increased ability for self financing and hence may be more likely to purchase and manage hybrid varieties which require extra costly inputs like seed and fertilizer.

Results reveal that households with more adults, as measured by the adult equivalent household size, are more likely to adopt hybrid maize than household with smaller numbers of adults. Labour is an important input in the production of maize. Larger household sizes are also associated with a higher availability of labor, which is required for the production of maize. The free input distribution program, had a positive and significant ($p<0.05$), effect on the adoption of hybrid maize. Inputs distributed under this program include maize seed and fertilizer, both of which have a direct impact on adoption of hybrid maize. The relative risk premium has no impact on the decision to adopt hybrid maize.

Land pressure, which is measured as the number of persons per hectare is negative and significant at 10 percent level. This indicates that households with more labour per hectare tend to have a lower likelihood of adopting hybrid maize. Experience has shown that households with larger pressure indices are also likely to be poor households hence less likely to have the earning power to be able to purchase costly innovations. In addition Tchale (2005) notes that increased pressure on agricultural land drives away excess labour to off-farm activities and the revenue generated from off-farm activities is seldomly used to finance the purchase of inputs. However, the variable has a positive and significant effect on the extent of adoption, signifying that once farmers are able to adopt hybrid maize, households with high land pressure will intensify their extent of adoption of an improved variety in order to maximize productivity required to meet their food and cash requirements from the small size of land. In most adoption studies, high land pressure has been described as a prerequisite for agricultural intensification.

5.2.2 Determinants of extent of adoption

The extent of adoption is measured as a proportion of land that is allocated to hybrid maize out of total maize land. Results on the determinants of the extent of adoption are presented in table 4. First, the inverse Mills ratio is significant implying that there is selection bias in the model and thus its inclusion in the model was necessary. The farmer's risk attitude towards fertilizer-use is measured by the variable 'relative risk premium'. As indicated in table 4, the relative risk premium is negative and significant in this second stage of the model. Thus, while risk aversion towards fertilizer-use does not appear to affect the decision to adopt, it significantly reduces the extent of adoption of hybrid maize. This implies that farmers that are more risk-averse towards the use of fertilizer are more likely to allocate larger portions of their land to local maize technologies that allow them to reduce the production risk related to fertilizer-use. The results comply with the expectation that farmers stick to the production of traditional varieties as a means of hedging against input related production risks.

The age of households head is significant and negative ($p<0.05$). Households headed by the elderly allocate smaller proportions of land to hybrid maize than those that are younger. At the time of the survey more than sixty percent of the heads of households were more than 40 years old. Individuals with ages greater than 40 years are usually associated with high risk aversion than those below the age of 40. While larger households are more likely to grow hybrid maize, results on extent of adoption show that they allocate much smaller proportions of land to hybrid maize than smaller households. This could be explained by the fact that once the decision to grow maize is made, based on the 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 maize. In most cases larger households are also poor households which may lack the financial capacity to purchase inputs.

While the free input distribution program leads to higher a likelihood of adoption in the first stage, GLM results on the extent of adoption indicate that free input recipients are associated with allocating of smaller portions of land to hybrid than those that did not receive free inputs. The main reason is that the free input distribution programs target the poorer households who are unlikely to extend hybrid cultivation beyond 0.25 hectares, the maximum size of land for which free inputs are provided. The variable capturing tobacco growing households is positive and significant ($p<1\%$). Tobacco growing households are usually wealthier households with financial capacity to purchase inputs such as fertilizer and seed, both of which are crucial for adoption.

6.0 Conclusions and Policy Implications

This paper has investigated the relationship between risk aversion towards the use of fertilizer and adoption. Using the moments based approach we empirically examined the relative risk premium related to fertilizer-use among farmers. We have shown that Malawian farmers exhibit absolute Arrow-Pratt risk aversion towards the use of fertilizer. We find that risk aversion on fertilizer-use negatively affects the extent of adoption of hybrid maize. The study reveals that when considering promoting the adoption of hybrid maize, it is important to assess the profit distribution and its implications for risk preferences towards the use of complementary inputs such as fertilizer. Failure to do so would lead to the formulation of wrong policies. Human and financial capital variables such as age, household size, size of land and off-farm income, have a significant impact on the adoption of hybrid maize. A notable finding is that while safety net programs such as the free input distribution increase the likelihood of adoption, they are associated with low levels of the extent of adoption. This emphasizes the lack of financial capacity to purchase inputs as a key constraint to adoption. Without necessarily underscoring budgetary implications, it is important for safety nets programs such as the Starter Pack Scheme and the Targeted Input program (TIP) that are being implemented in Malawi to have their packages revised upwards in order to increase the extent of adoption for hybrid maize.

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Appendix

Table 1: Descriptive statistics of selected variables

Variable	Adopters (n=161)	non-adopters (n=243)	Total (n=404)
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(ha)	1.8	1.5	1.7
Land pressure index	1.4	1.2	1.3
Credit access (MK/year)	346	232	300
Livestock ownership (%)	53	65	58
Asset value (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 IFPRI/RDD data

Table 2: Risk aversion indicators

Risk parameter	COEFF	T-Statistic
Constant	-0.006108	-0.271
Q2 (associated with AP)	2.05526**	2.203
Q3 (associated with DS)	-1.419432***	-2.987

Source: Own calculation from IFPRI/RDD data
, * represent significance at 5% and 1%, respectively.

Table 3: Determinants of decision to adopt- Logit estimates

	Likelihood of adoption	
	Coefficient	**t-statistic**
Constant	-1.0782	2.3128
Off-fam income	0.0001*	3.1100

Gender of head (1=male)	-0.0823	0.0612
Age of head	-0.0180*	3.1570
Total asset value	0.0000	0.3650
Household size	0.2409**	5.7341
Land holding	0.5416**	6.0679
Education of head	-0.0627	0.0333
Education of spouse	0.0681	0.0481
Free inputs	1.0352**	6.6299
Tobacco household	-0.2099	0.2155
Distance Extension Office	0.0040	0.0096
Access to credit	0.0004	2.2864
Land pressure	-0.1565*	3.4360
Relative risk premium	3.7279	0.8364
Mangochi	2.4414***	28.003
Nkhota	0.3999	0.6635
Rumphi	0.3674	0.3552
Dedza	-1.3242***	11.282
No.obs	404	
Log likelihood	-352.706	
Chi square	192.788**	

Source: Own calculation from IFPRI/RDD data
, * represent significance at 5% and 1%, respectively.

Table4: GLM estimates of the Determinants of the Extent of Adoption

Variables	Coefficient	Robust standard errors	Z	P value
Constant	2.51849***	0.63738	3.95000	0.00000
Off-fam income	0.00001	0.00002	0.59000	0.55300

Gender of head (1=male)	0.09124	0.25764	0.35000	0.72300
Age of head	-0.01900**	0.00848	-2.24000	0.02500
Total asset value	0.00006	0.00004	1.47000	0.14200
Household size	-0.14900*	0.07712	-1.93000	0.05300
Land holding	-0.01422	0.08559	-0.17000	0.86800
Education of head	0.13709	0.25908	0.53000	0.59700
Education of spouse	-0.29153	0.26448	-1.10000	0.27000
Free inputs	-0.29823**	0.14191	-2.10000	0.03600
Tobacco household	0.65716***	0.24843	2.65000	0.00800
Distance to Extension Office	-0.02798	0.03130	-0.89000	0.37100
Access to credit	-0.00006	0.00007	-0.89000	0.37500
Land pressure	0.22064**	0.10761	2.05000	0.04000
Relative risk premium	-0.56208**	0.18890	-2.98000	0.00300
Mangochi	1.03084**	0.43157	2.39000	0.01700
Nkhota	1.67449***	0.58909	2.84000	0.00400
Rumphi	-1.13497***	0.33120	-3.43000	0.00100
Dedza	-0.28698	0.32779	-0.88000	0.38100
Inverse Mills ratio	-0.70968**	0.28429	-2.50000	0.01300
No.obs	241			
Deviance	127.74			
Chi square	83.65			
-Log likelihood	-78.188			