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Response to Climate Risks among Smallholder Farmers in Malawi: A Multivariate Probit Assessment of the Role of Information, Household Demographics and Farm Characteristics

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Abstract

Located in southern Africa, Malawi is a country increasingly facing numerous climate-related stressors including droughts and floods. Adaptation to these stressors is critical to the sustainability of the farming systems in the country. Using household and plot level data collected in 2011, we implement a multivariate probit model to assess the determinants of farmer adaptation behavior to climatic risks. The ex-ante adaptation practices considered by farmers include: planting drought, disease and pest tolerant varieties, early planting, soil and water conservation and crop diversification. We find that plot characteristics, credit constraints and availability of climate-related information explain the adoption of several of these adaptation practices. We also find that even when financial limitations are binding, availing climate-related information still motivate farmers to adapt. Policy effort to build resilience among rural farming systems should focus on extension education and information delivery with special emphasis on climate risks information and associated adaptation mechanisms.

Key words

Climate risks, Adaptation, Multivariate probit, Smallholder farmers

1. Introduction

There is a universal understanding among the global scientific community and general publics that considerable changes in the earth's climate are apace. It has been reported that in the last twenty years preceding 2005, there has been a marked increase in economic damages from extreme weather events (Munich RE, 2008). Studies have established a link between adaptation and (under) development implying inability to cope with climate change and subsequent challenge in the fight to eradicate poverty amongst the poor in under developed and developing world(Ayers, Huq, Faisal, & Hussain, 2014). Thus in the face of climate change, the impact continues to be disproportionate on sub-Saharan Africa (SSA) and similar areas in South Asian countries, where over 325 million people are projected to be trapped in poverty by 2030(World Bank, 2013). For the most part, countries in SSA have the least capacity to cope with climate shocks and their negative environmental and human consequences. India and Africa are projected to see reductions in agricultural output by 30% or more (Cline, 2007). The situation is worse in Africa where for a long time, agricultural production has performed unsatisfactorily especially when compared to Asia over a 50-year time period from 1961 to 2007(Pretty, Toulmin, & Williams, 2011).

Agriculture, as a natural resource based industry will be affected by climate change more than any other sector. Yet, much of the discourse on climate change has been on the mitigation of the causes of climate change like industrial CO_2 emissions (IPCC, 2007). With the current agreements on limiting carbon emissions not likely to stabilize concentrations of greenhouse gases in the atmosphere over the next few decades, agricultural productivity is projected to diminish further(Salvatore Di Falco & Veronesi, 2013; R Mendelsohn, Nordhaus, & Shaw, 1994). Taking adaptation measures at the farm level should thus be part of the package in the critical responses needed to deal with climate change (Burton, Huq, Lim, Pilifosova, & Schipper, 2002). Farmers need to change their practices to cope/adapt in the face of rapidly changing climatic conditions. Adapting means, *inter alia* changing crop or livestock enterprises, use of more or less of certain inputs, implementing new resource management practices, diversifying farming systems and sometimes diversifying into non-farm activities (Howden et al., 2007). Assuming economic rationality, farmers will seek to balance the benefits and costs of these new actions demanded by changing climatic conditions. Only when the net expected benefits of adaptation are positive will rational decision makers take adaptive actions (Antle 2009). As one of the benefits of adaptation, farmers may reduce yield variability over time enabling them to respond to the vagaries of climate change.

1.1 Country background and Agro-climatic situation

Rain-fed small-holder agriculture continues to dominate most economies of SSA. In Malawi, where over 74% of the population lives on less than 1.24 dollars per day (OECD, 2009), agriculture contributes over 39% to the GDP and employs about 85% of the country's entire labor force (Chirwa, Kumwenda, Jumbe, Chilonda, & Minde, 2008). Though agriculture continues to play this important role in Malawi's economy, a myriad of setbacks inflict it. Decades of intensive cultivation like the predominant ridging practice coupled with inadequate use of capital (fertilizers, soil conservation, and mechanization) have led to nutrient depletion and stagnation in productivity (Denning et al., 2009). Low investments in soil fertility management and increasing climate shocks over the last five decades have further compounded the problem leaving the sector increasingly vulnerable (Binswanger-Mkhize et al. 2011)

For the last two decades, droughts, floods and dry spells in Malawi have increased in frequency, intensity and magnitude exacerbating rural poverty and threatening the sustainability of rural livelihoods (Ibrahim & Alex, 2008; Nangoma, 2007). Against the backdrop of rapidly changing climatic conditions and severity of the impact on poor subsistence farmers, there is an urgency to better understand the adaptation options that farmers face, their perception towards these and the determinants to adopting them. Therefore, this study provides insights into some of the adaptation options farmers' face and the barriers to adopting them either as substitutes and/or as a batch of complimentary options.

1.2 Climate change adaptation

Several climate change adaptation strategies are identified in the literature and include: 1) use of adaptive crop varieties (drought tolerant (DT) and pest and disease tolerant (PDT) varieties); 2) changing the timing of agricultural activities (early planting, EP); 3) diversification of crop enterprises (CD) and 4); investment in soil and water conservation technologies (SWC) (Di Falco et al. 2011; Antle 2009; Kurukulasuriya and Mendelsohn 2008; Amsalu and de Graaff 2007). Despite the documented benefits of these practices in adapting to climate change, their uptake has been slow in Malawi and the broader region (Jain, 2007; Nhemachena & Hassan, 2007). It is still not clear why, faced with climatic risks, farmers are not implementing practices that appear to demand modest amounts of external capital. Other than SWC, which may require increased amount of labor, the other practices (DT, PDT, EP and CD) do not require large adjustments. Taking into consideration the expected benefits, the costs of such adjustments may well be justified.

The assumption that these practices require minimal capital and labor outlays could also bean empirical issue rather than a universal fact or as we hypothesize in this study; that factors related to information, household capital endowments and farm characteristics can offer insights into the observed patterns of sluggish adoption of adaptation practices. While acknowledging that capital could be a barrier to adoption of modern technologies such as fertilizers as the literature has shown, there are large gaps in the adoption literature as to why relatively simple and accessible agronomic and/or management practices are not adopted by many farmers to manage climate related risks.

The list of literature related to adaptation to climate change is still growing(World Bank 2013; Antle 2009; Kurukulasuriya & Mendelsohn 2008; Mendelsohn 2000). Climate change adaptation studies in the context of Southern Africa are also extant. While most of these use single adaptation options (e.g. Kurukulasuriya and Mendelsohn 2008; Seo and Mendelsohn 2008), Nhemachena & Hassan (2007) uses a multivariate probit method to investigate barriers to climate change adaptation in the context of South Africa, Zambia and Zimbabwe. Using the same econometric approach, we add to the literature by incorporating both plot level and household level variables in analyzing climate change adaptation in the context of Malawi. To our knowledge, no study has been carried out to investigate the adoption of specific practices as a direct response to climatic risks and therefore as means of climate change adaptation in Malawi. Many previous studies have focused on adoption as a way to achieve higher productivity ignoring the need to adapt to new production conditions as dictated by on-going climatic changes.

We use a rich dataset comprising plot level data (5641 plots) and household level data (1786 households) to investigate the factors that determine the interdependent adoption of multiple adaptation strategies like DT, PDT, EP, CD and SWC. This primary dataset was collected by the Department of Agricultural Research Services in Malawi (DARS) in collaboration with the International Maize and Wheat Improvement Centre (CIMMYT) in 2011.We particularly explore the relationships in the adoption of these strategies either as substitutes or compliments in combating a myriad of climate change related risks.

The contribution of our paper is two-fold. First using a multivariate probit framework, we are able to capture the complementarities and substitutabilities among the various practices that can be implemented on-farm for maximum benefit. Secondly, we use the results from the multivariate model to simulate the impact of key policy variables to compare the impact of information relative to that of resources in explaining adoption outcomes. The reviews conducted for this paper show that the *relative* importance of family labor, liquidity and information remains an empirical question and is largely a function of local circumstances including agro-ecological conditions and policy situations (Marra, Pannell, & Abadi Ghadim, 2003). Our simulations enable us to identify the relative impact of information and resources in a way that can help in priority setting.

2. Conceptual framework

Adaptation strategies are a form of protection measure that reduces the farmers' risk exposure by reducing the marginal effect of climate change effect on productivity(Fisher-Vanden and Wing 2011). We adopt a utility maximization function in the presence of risk to analyze adaptation decisions. In our case, the utility to a farmer need not be defined by higher yields. In the context of adaptation, the utility derived from adopting an adaptation strategy could be yield stability and the implied reduction in downside risk. A risk-averse farmer maximizes utility by choosing an adaptation strategy if the benefits of adaptation (risk reduction) less the cost of adaptation are higher than the benefits realized without adaption. Following Hazell & Norton (1986), we define the utility function as follows;

$$U_y = E_y - \alpha\omega_y$$

Where U_y is the perceived utility from choosing adaptation strategy y, E_y is the non-stochastic component and ω_y is the disturbance term indicating variation in yields. $\alpha$is a coefficient that captures risk aversion of individual farmers which would affect the degree of the variability in the yields ω_y. Following Finger & Schmid(2007), we define this coefficient as;

$$\alpha = -(\partial U/\partial \omega_y)/(\partial U/\partial y)$$

Where if $\alpha < 0$, the farmer is risk averse and thus more likely to adapt; $\alpha = 0$ indicates a risk neutral farmer and $\alpha > 0$ indicates a risk loving one. The utility of implementing a strategy

$y(U_y)$ is given by the revenues generated by the strategy less the variable costs incurred in implementation.

Given an array of adaptation strategies, a risk-averse farmer will choose the strategy, say X, that yields higher expected utility than the alternatives, say Y, i.e.

$$E(U_x) - M_x > E(U_y) - M_y$$

Where the first term is the expected utility of implementing strategy X and the associated costs M_x, while the second term is the expected utility of implementing strategy Y and associated cost M_y. Assumptions about the relationship of disturbance terms of the adaptation equations i.e. whether correlated or not, determine the type of qualitative choice model to use in analysis.

3. Methodology

3.1 Multivariate probit model

Faced with adverse climatic changes, farmers opt to adopt a mix of strategies as a way of mitigation rather than relying on a single strategy to exploit complementarities among alternatives. Thus in addition to adopting SWC, a farmer may also choose to practice CD, EP, DT or PDT. Adoption could also be path dependent with earlier adopted strategies informing decisions on subsequent practices in the future. It is thus necessary to use a model which estimates the influence of exogenous factors on the adoption of the strategies simultaneously while allowing for the error terms of each of these strategies to be freely correlated, failure to which lead to biased estimates (Kassie, Jaleta, Shiferaw, Mmbando, & Mekuria, 2013; Lin, Jensen, & Yen, 2005). We thus employ a multivariate probit model in this study to investigate the inter-dependent strategy adoption decisions.

We follow Lin et al. (2005) in formulating the multivariate model which has 5 dependent variables, $y_1, \ldots, y_5$ such that;

$$y_i = 1 \qquad if \qquad \beta_i x' + \varepsilon_i > 0$$

and

$$y_i = 0 \qquad if \qquad \beta_i x' + \varepsilon_i \leq 0 \qquad\qquad i = 1,2, \ldots ,5$$

Where x is a vector of the explanatory variables; $\beta_1, \beta_2, \beta_3, \beta_4, and\ \beta_5$ are conformable parameter vectors and $\varepsilon_1,\ \varepsilon_2, \varepsilon_3, \varepsilon_4\ and\ \varepsilon_5$ are random errors distributed as a multivariate normal distribution with zero mean, unitary variance and an $n \times n$ correlation matrix.

3.2 Independent Variables and Hypotheses

This study incorporated the explanatory variables based on the review of existing literature on adoption studies and climate change adaptation, conceptual framework and the availability of the variables in the dataset. These variables can be grouped into plot level characteristics and household/farm level characteristics.

3.2.1 Plot level characteristics

Variables under this category include, land tenure (1=owned; 0=not owned including borrowed, rented in and communal land); soil fertility (1=fertile; 0=lower/medium fertile); and soil slope (1=gently sloped; 0=more sloped/medium slope). Long term investments in land are positively correlated with ownership of the said land. Strategies like SWC which require considerable investments with benefit streams accruing in the long-term are likely to be implemented by households who actually own the land and have security of tenure (Kassie et al. 2013; Amsalu and de Graaff 2007).

Farmers with fertile plots generally realize higher returns even without much investment in management. Such farmers may therefore be reluctant to invest in relatively costly inputs like drought or disease tolerant seeds or SWC like terracing, unless the productivity impacts are substantial. This course can be detrimental in the long run if it creates complacency about the need for soil recapitalization, but many farmers' planning horizons may not extend into the distant future where the benefit of increased soil fertility manifests itself. This variable is thus generally expected to have a negative sign on most of the adaptation strategies. Likewise, gently sloped plots are less prone to soil degradation through erosion. Farmers who have such plots are generally expected to invest less on SWC and other soil fertility management strategies (S. Di Falco et al., 2011).

3.2.2 Household characteristics

Important variables considered under household characteristics include those related to household capital and information access. Household capital can be categorized into physical, social, human and financial capital. Physical capital considered in the study was in the form of livestock ownership. Livestock is a form of saving and insurance (Bosman, Moll, & Udo, 1997; Doran, Low, & Kemp, 2014). The number of tropical livestock units (TLU) owned by a household is an indicator of wealth status in rural areas. Households with a higher TLU value can afford to take risks and rely on the livestock in times of climate shocks(Jones and Thornton 2009). It could also be argued that famers with more assets have the capacity to undertake capital-demanding technologies. One way of increasing adoption rates is to develop technologies that do not require expensive investments, which also increase farmers' vulnerabilities in case of crop failure (Muzari, Gatsi, & Muvhunzi, 2012). The association between physical asset endowment (TLU) and adaptation is expected to be positive.

Social capital in our study is proxied by kinship ties and group membership. Through kinship ties, households are able to take advantage of human capital as well as asset stocks that come with new technologies (Parthasarathy and Chopde 2001). Members of a certain group (including neighbors) are able to share information among themselves which accelerates the process of technology adoption and diffusion (Munasib and Jordan 2011). Thus the expected sign of social capital and adaptation is positive.

Human capital considered includes health status of members, age, education and skills. Adoption studies point to a positive relationship between education levels and technology adoption (Czaja, Charness, & Fisk, 2006) but are divided on the effect of age (Akudugu, Guo, & Dadzie, 2012; D'Souza, Cyphers, & Phipps, 1993; Uaiene, 2008).We thus hypothesize a positive relationship between education level and adaptation but are indeterminate on age.

Previous studies have argued of a systematic bias against women which lowers adoption rates in this group (Uaiene, 2008). Still, other studies present women as risk averse hence more likely to adopt technologies which would lower their risk exposure (Arano, Parker, & Terry, 2010).Thus the direction of the association between adaptation and gender of the household head is indeterminate.

The credit constraint variable categorized farmers into those who needed credit and did not get it or got less than the needed (=1) and those who did not need credit (=0). Credit access relaxes liquidity constraints thus increasing technology adoption (Simtowe and Zeller 2006). We thus expect a negative relationship between credit constraint and the probability of observing an adaptation practice.

Participation in non-farm income activities has been shown to increase technology adoption (Fernandez-Cornejo and Mishra 2007), though other findings give different opinions. For example, Diiro (2009)established that farmers without off-farm activities use all the available labor more intensively on farm and hence adopt yield increasing technologies more. The expected sign of the relationship between income and adoption of climate adaptation strategies can be indeterminate.

Lack of and/or limitations in information (on seasonal and long-term climate changes and agricultural production) increases downside risks due to failure to adopt new technologies and adaptation measures (Kandli and Risbey 2000).Better climate and agricultural information help farmers choose strategies that enable them to cope well with changes in climatic conditions (Baethgen, Meinke, & Gimenez, 2003).Accordingly and in line with technology adoption literature, the general sign expected with access to extension is positive (Amsalu and de Graaff 2007).

3.3 Data sources and sampling

The study was conducted in 16 districts across the country's three administrative regions. Six of the districts included in the sample form the study areas of a CIMMYT-led project on Sustainable Intensification of Maize and Legume cropping systems for food security in Eastern and Southern Africa (SIMLESA). To broaden the scope and have a nationally representative sample, 10 more districts were included in the study.

The study is based on a primary survey of 1786 households located in the three regions of Malawi. Malawi's four Agro-Ecological Zones (AEZ's); Lower Shire Valley (<200m), Low altitude (200-760m), Middle altitude (760-1300m) and High altitude (>1300m);formed the strata for the sample frame where random proportionate sampling was employed to select 16 districts. Proportionate (to size) random sampling was used to select the Extension Planning Areas (EPA) included in the sample frame from which the 1786 households were randomly and proportionately selected.

Data were collected using a detailed structured questionnaire. Questions included in the survey instrument were targeted to capture the exposure of the households to climate risks over time and whether farmers had made any changes to their farming practices in response to these changes. Over 95% of the interviewed farmers' responded positively to having been exposed to a climate risk in the past. Specifically, 98% had been exposed to drought, 92% to floods, and 97% to crop pests and diseases while a further 90% had been exposed to hailstorms. To understand whether such risks took place over time, the survey instrument was designed with a 10 year recall where famers were asked to indicate the number of times each risk had occurred within that time frame.

The survey instrument also included a question on the adaptation measures that farmers had taken as a result of a past climate risk exposure which included, EP, DT, PDT, CD and SWC. Of the farmers who had any adaptation strategy, 85% of these were yield related while the remaining 15% were non-yield related. About 32% of the farmers who had an exposure to risks in the past did not implement any adaptation strategy. Very few of the farmers exposed to drought in the past had not implemented a mitigation strategy while a higher percentage of those affected by hailstorms did nothing to mitigate its effects in case of a future occurrence.

Specifically, farmers who reported DT as an adaptation strategy were 39% while 27% reported to have practiced EP (table 1). The least used strategy was SWC measures. About 35% and 36% used PDT and CD, respectively. The data show that over 83% of the households were male-headed and the average age and years of education of the household head were 50 years and 6 years. On extension access, about 47% of the interviewed households had accessed this through contacts with government extension agents, 35% through neighbor farmers and 39% through the media (radio and/or TV).Cumulatively, about 59%of the total sample had access to any of the three sources of extension. Access to credit is a major constraint with about 65% of the sampled households being credit constrained.

4. Results and Discussions

This section discusses the results from the multivariate probit model. We also present results from individual probit equations for comparative purposes.

The likelihood ratio test ($chi^2(10)$ =867.62, P<0.000) of the independence of the error terms of the different adaptation equations is highly rejected (table 2).We thus adopt the alternative hypothesis of the mutual interdependence among the multiple adaptation strategies. The result thus supports the use of multivariate probit model (as explained under the section on empirical model).

Most of the pairwise coefficients are also revealed to be positively correlated indicating complementarity among these strategies. DT is positively correlated with EP indicating that farmers who use these varieties couple it with planting the seed early. The same applies for PDT and DT indicating that farmers use seeds with a combination of these characteristics. The association between SWC and EP is negative perhaps since use of SWC to conserve moisture may be substituted by less resource-demanding EP which then utilizes early rains to counter the moisture deficit.

Parameter Estimates: Multivariate Probit Model

The results on parameter estimates from the multivariate probit and individual probit models are presented in table 3. Variables related to *plot* and *household characteristics* as well as *information access* are significant in informing adaptation to climate change. In regard to *plot characteristics*, and consistent with Di Falco et al. (2011), we find that farmers with fertile plots are less likely to use DT, EP and CD. These plots will more likely require lower levels of inputs to achieve the same level of yield compared to older and poorer plots. Rather than invest expensive inputs in these better off plots, farmers may rationally save their resources for other uses or for investing in poorer plots. Total crop failure is also less likely in fertile soils thus farmers with such plots can afford to specialize in few lucrative crops rather than diversify into many smaller crop enterprises. Consistent with Barungi et al. (2013), the probability of adopting SWC and EP increases with medium to steep slopes.

Access to climate-related information significantly determines adaptation across most strategies. This underscores the important role of availing climate related information to farmers. Adaptation requires that farmers first notice that the climate has changed, and then identify useful adaptation strategies and implement them (Maddison, 2006). Specifically, access to government extension increases the probability of adaptation through EP and CD. Informal sources like neighbor-spread information increase the likelihood of adaptation through CD while information spread through the media increases the likelihood of adaptation through most of the strategies.

We also find that access to credit is a major determinant of the decisions to adapt to climate change. With resource limitations, farmers may fail to meet the costs of adaptation and at times cannot make beneficial use of available information (Kandli and Risbey 2000). Credit constrained households are less likely to adapt through any of the five strategies. Adaptation strategies are expensive with some requiring the purchase of new adaptive seeds while others are resource intensive (e.g. SWC). All these entail committing substantial scarce resources considering that majority of the Malawian population live on less than $1.24 per day. Thus in the absence of microcredit, farmers may still find it difficult to adapt even when provided with information on climate change because they are unable to purchase the requisite inputs.

In line with Velandia et al. (2009) but contrary to (Fernandez-Cornejo & Mishra, 2007),we find that households that have access to off-farm income are less likely to adapt through DT, EP and CD. Depending on the proportion of total household income emanating from non-farm income, and the prevailing non-farm wages and therefore the opportunity costs of farm labor, farmers with access to non-farm incomes may be less exposed to production risks because their reliance on agricultural income and own food production is lower than that of the median rural household.

We also find that farmers who trust the government for support in case of crop failure are more likely to adapt through PDT and CD. Those with less trust in government support are however more likely to use EP which would cushion them against total crop failure.

We converted the total farm labor count to male labor equivalent (Rada and Valdes 2012). The amount of male labor available to the households positively affects the decision to adapt by CD and SWC. These strategies may require more labor allocation thus would be adopted more by labor-rich households.

Diverging from findings by others (Kassie et al. 2013; Amsalu and de Graaff 2007), we find that village kinship ties have a positive impact in adaptation strategies especially in DT and CD. More kinship ties may act as a form of group dynamics facilitating flow of information from a kin to another, hence easier and faster uptake of technologies. Further, sharing of seed in form of gifts amongst kins may also contribute to greater spread of improved seed use across these ties.

Consistent with others on the effect of education on technology adoption (Asafu-Adjaye, 2008; Velandia et al., 2009), we find that household heads with more years of schooling are more likely to adapt through DT and CD. Risk mitigation through CD is knowledge-intensive which might explain why more educated farmers adopt this. Also, with more education people are able to open up to new ideas and thus be more receptive to technology change.

Household specific factors like the age and gender of the household head also significantly affect adaptation to climate change. Older household heads are more likely to adapt through CD perhaps due to accumulated farming and risk experiences. On the other hand, male-headed households are positively associated with EP which may be explained by more labor availability and asset endowment characteristic of male-headed households (Ragasa, Berhane, Tadesse, & Taffesse, 2013).

Similar to others (Kassie et al. 2009; Amsalu and de Graaff 2007), we find that the adoption of DT and SWC is limited by livestock ownership. Livestock may act as a coping strategy after risk occurrence with these either being sold or used for food. Farmers with higher TLU are thus less risk averse and act less to mitigate against climate risks.

Discussed above are the parameter estimates from the multivariate probit model. For comparison, we also report on the parameter estimates from the individual probit model. The results from the two estimation procedures are fairly similar with regard to the significant variables and the direction of the effect. However, the multivariate probit model is superior in that we can be able to compute the probability of adoption of one strategy conditional to the others, as explained hereafter.

We simulated the impacts of a selected set of variables to show their impact on the marginal probability of success (MPS) or the probability of observing adoption of one practice conditional on the other practices (table 4). The simulated impacts of access to credit, education level of the household head, availability of extension and access to climate information showed that the variable with the biggest impact on MPS was access to climate information. The impact of making climate information universally available was as much as 45% on MPS in the case of CD. It was also the single variable with the highest MPS percentage across all the 5 strategies. Also important is access to credit where the removal of credit constraint highly increased the MPS across all the strategies, second only to universal availability of climate related information. The reverse is true in a scenario of total lack of climate information which had the least MPS across all the strategies, followed by the scenario of universally credit constrained farmers in this respect. The effect of completing primary schooling (raising the average years of schooling as observed in the sample by one year),was about 30% for DT. The next highest impact of primary school completion was 1.3% and the lowest impact was at 0.3% in the case of MPS for EP. In the case of extension, the highest impact on MPS was 19% for EP and lowest 3.2% for DTV.

Overall, these simulated effects show that information and liquidity offer a clear entry point for strengthening the adaptive capacities of farmers with respect to climate change. To further assess the relative importance of these two variables in influencing adaptation, we ran a multivariate probit on a sub-sample of credit constrained households (S. Di Falco et al., 2011). Results show that information access variables are still highly significant, further asserting the importance of availing climate information relative to credit provision. The importance of information access is crucial because even when famers can access the capital needed to implement these beneficial practices, they can still fail to do so if they erroneously view them as unprofitable or lack the information and skills to implement them. Extension programs that are designed as educational platforms to impart correct information and knowledge can help resolve these contradictions in farmer technology adoption behavior.

5. Conclusions

This paper analyzes the determinants of climate change adaptation strategy, using detailed plot level observations and the multivariate probit model. The null hypothesis of the independence of the different adaptation strategies was rejected. We thus adopt the alternative hypothesis of inter-dependence among the different adaptation strategies which justifies the use of the multivariate probit for this analysis. This result is important in informing extension policies on which strategies can be implemented together and which can be substituted, for greater effect.

One of the key findings from the study is that access to climate information is a main driver of the decisions to adopt the adaptation practices. Various sources of extension information significantly inform adoption decisions. Key among these is government extension and information accessed through the media. Awareness of climate change and measures to mitigate its effects is thus depicted as a key hurdle in the adaptation process. The study also identifies credit constraint as a key impediment to adaptation. Resource availability enables farmers to implement adaptation decisions, lack of which presents the household with a significant challenge of adopting the adaptation measures.

It also emerges from the study that credit constrained households are still able to adapt when provided with climate change related information. Our study therefore identifies lack of information as the most important deterrent to climate change adaptation by the farm household.

These results have important policy implications. There is need for clearly designed policies to disseminate climate change information to farmers. The same should incorporate deepening of extension access with information on the appropriate adaptation strategies. Important also is the need for fostering credit markets for easy accessibility and affordability by the farmers. These specific policies geared towards overcoming information and resource constraints would lead to high adoption of crop varieties adapted to changing growing conditions and the implementation of agricultural practices that stabilize yields thus enabling farm households to successfully respond to climate change.

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Tables

Table 1: Sample distribution

Region	District	Female Headed	Male Headed	Total	% of total
North	Mzimba	17	170	187	10
Central	Denza	24	83	107	6
	Kasungu	4	98	102	6
	Ntcheu	22	85	107	6
	Dowa	11	102	113	6
	NTCHISI	7	45	52	3
	Salima	19	59	78	4
	Mchinji	14	46	60	3
	Lilongwe	31	279	310	17
South	Balaka	40	110	150	8
	Blantyre	13	56	69	4
	Chiradzulu	16	41	57	3
	Machiga	22	107	129	7
	Mang'ochi	29	119	148	8
	Mwanza	12	24	36	2
	Thyolo	18	63	81	5
	Total	**299**	**1487**	**1786**	**100**

Table 2: Risk exposure and coping strategies

	Drought			Floods			Crop pests			Hailstorms			Total		
	Obs	Freq	%	Obs	Freq	%	Obs	Freq	%	Obs	Freq	%	Obs	Freq	%
Farmers exposed to risk	1526	1491	98	813	746	92	1147	1111	97	776	702	91	4262	4050	95
Category of coping strategy															
None	1493	251	17	750	285	38	1112	359	32	704	441	63	4059	1336	33
Yield-related	1493	1088	73	750	385	51	1112	654	59	704	180	26	4059	2307	57
Non-Yield related	1493	154	10	750	80	11	1112	99	9	704	83	12	4059	416	10

Table 3: Descriptive statistics (household level, *n*=1786; plot level, *n*=5641)

Variable	Description	Mean	Std Dev.
Dependent variables			
Planting drought tolerant varieties	Dummy=1 if household adapted drought tolerant varieties as an adaptation strategy, 0 otherwise	0.3914	0.0115
Practicing early planting	Dummy=1 if household adapted early planting as an adaptation strategy, 0 otherwise	0.2725	0.0105
Planting disease/ pest tolerant varieties	Dummy=1 if household adapted disease/ pest tolerant varieties as an adaptation strategy, 0 otherwise	0.3501	0.0113
Crop diversification	Dummy=1 if household adapted crop diversification as an adaptation strategy, 0 otherwise	0.3618	0.0114
Practicing soil and water conservation measures	Dummy=1 if household adapted practicing soil and water conservation measures as an adaptation strategy, 0 otherwise	0.0854	0.0066
Explanatory variables			
Farm characteristics			
Land tenure	Dummy=1 if plot is owned, 0 otherwise	0.9463	0.0030
Fertile soil	Dummy=1 if plot is highly fertile, 0 otherwise	0.4724	0. 0067
Medium fertile soil	Dummy=1 if plot is of medium fertility, 0 otherwise	0.3969	0.0065
Gentle slope	Dummy=1 if plot is gently sloped, 0 otherwise	0.6088	0.0065
Medium slope	Dummy=1 if plot is of medium slope, 0 otherwise	0.2775	0.0060
Farmer and household characteristics			
Sex	Gender of household head, 1= male, 0 otherwise	0.8319	0.0091
Age	Age of household head in years	41.9035	0.3495
education	Years of education of the household head	5.7632	0.0901
Distance to main market	Distance to the main market in walking minutes	83.2340	1.5172
Distance to agricultural extension	Distance to the agricultural extension offices in walking minutes	80.6675	1.5478
Membership to farmer groups	Dummy=1 if household head or spouse are members of a farmer group, 0 otherwise	0.1036	0.0074
Number of relatives in village	Number of relatives the household can rely on in the village	3.2416	0.0781
Reliance on government support	Dummy=1 if household can rely on government support in times of need, 0 otherwise	0.5944	0.0135
Labor (male person days)	Total labor committed to the plot in male person days	51.5906	0.6041
Off-farm income	Dummy =1 if household has access to off-farm income, 0 otherwise	0.7342	0.0108
Drought experience	Dummy =1 if the household has ever experienced a drought, 0 otherwise	0.8289	0.0092
Credit constrained	Dummy =1 if household is credit constrained, 0 otherwise	0.6501	0.0117
Assets			
TLU[a]	Total Livestock Units	0.6822	1.0422
Information access			
Access to government extension	Dummy =1 if household had access to government extension, 0 otherwise	0.4660	0.0121
Neighborhood extension	Dummy =1 if household had access to neighbor extension, 0 otherwise	0.3529	0.0116
Radio/TV extension	Dummy =1 if household had access to radio/TV extension, 0 otherwise	0.3919	0.0119
Access to climate information	Dummy =1 if household had access to any information on climate change, 0 otherwise	0.2670	0.0108

[a] Total Livestock Units as defined in Storck et al. 1991

Table 4: Correlation coefficients of the climate change adaptation strategies (from the multivariate probit estimation)

Climate change adaptation strategy	Correlation coefficient	Standard Error
Drought tolerant varieties and Early planting	0.2508***	0.0221
Disease/pest tolerant varieties and drought tolerant varieties	0.3762***	0.0203
Crop diversification and drought tolerant varieties	0.2899***	0.0211
Soil & water conservation measures and drought tolerant varieties	-0.0204	0.0315
Disease/pest tolerant varieties and early planting	0.2422***	0.0214
Crop diversification and early planting	0.1702***	0.0222
Soil & water conservation measures and early planting	0.0364	0.0317
Crop diversification and disease/pest tolerant varieties	0.3426***	0.0201
Soil & water conservation measures and disease/pest tolerant varieties	-0.1339***	0.0314
Soil & water conservation measures and crop diversification	-0.1538***	0.0302

Likelihood ratio test of rho21 = rho31 = rho41 = rho51 = rho32 = rho42 = rho52 = rho43 = rho53 = rho54 = 0

chi2 (10) = 867.62 Prob>chi2=0.0000

*** $p < 0.01$

Table 5: Parameter estimates from multivariate probit and individual probit for estimating determinants of adaptation to climate change

Variable	Multivariate probit estimates					Individual probit estimates				
	Drought tolerant varieties ***DT***	Early planting ***EP***	Disease/ pest tolerant varieties ***DPT***	Crop diversification ***CD***	Soil and water conservation measures ***SWC***	Drought tolerant varieties ***DT***	Early planting ***EP***	Disease/ pest tolerant varieties ***DPT***	Crop diversification ***CD***	soil and water conservation measures ***SWC***
Farm characteristics										
Land tenure	0.0940	-0.0430	-0.0688	-0.0975	-0.1885*	0.1048	-0.0473	-0.0481	-0.0886	-0.1864*
	(0.0887)	(0.0817)	(0.0786)	(0.0801)	(0.1067)	(0.0888)	(0.0812)	(0.0787)	(0.0802)	(0.1070)
Highly fertile soil	-0.1335**	-0.0722	0.1818***	-0.2377***	0.1219	-0.1309**	-0.0777	0.1925***	-0.2318***	0.1416*
	(0.0602)	(0.0575)	(0.0570)	(0.0560)	(0.0781)	(0.0607)	(0.0576)	(0.0581)	(0.0566)	(0.0788)
Mid-fertile soil	0.0620	0.0337	0.3902***	-0.1479**	-0.2026**	0.0649	0.0406	0.4152***	-0.1359**	-0.1895**
	(0.0612)	(0.0584)	(0.0578)	(0.0572)	(0.0835)	(0.0616)	(0.0584)	(0.0588)	(0.0576)	(0.0844)
Gentle slope	0.5039***	-0.0979**	0.2848***	0.4134***	-0.2087***	0.5401***	-0.0891*	0.2945***	0.4311***	-0.2239***
	(0.0668)	(0.0589)	(0.0589)	(0.0587)	(0.0781)	(0.0678)	(0.0594)	(0.0594)	(0.0593)	(0.0782)
Medium sloped	0.4163***	-0.2210***	0.1558**	0.2023***	-0.2128**	0.4486***	-0.2099***	0.1749***	0.2271***	-0.2335***
	(0.0719)	(0.0647)	(0.0640)	(0.0640)	(0.1338)	(0.0728)	(0.0651)	(0.0645)	(0.0646)	(0.0859)
Household characteristics										
Sex	0.0007	0.1860***	0.0857*	-0.0271	0.1029	-0.0057	0.1868***	0.0863*	-0.0309	-0.1138
	(0.0543)	(0.0543)	(0.0510)	(0.0507)	(0.0738)	(0.0545)	(0.0547)	(0.0515)	(0.0513)	(0.0743)
Age	0.0003	-0.0010	-0.0000	0.0040***	-0.0003	0.0003	-0.0012	-0.0003	0.0038***	-0.0004
	(0.0012)	(0.0012)	(0.0011)	(0.0012)	(0.0016)	(0.0011)	(0.0012)	(0.0011)	(0.0012)	(0.0016)
education	0.0142***	-0.0052	0.0011	0.0087**	-0.0057	0.0147***	-0.0058*	0.0004	0.0098**	-0.0051
	(0.0043)	(0.0033)	(0.0032)	(0.0038)	(0.0038)	(0.0043)	(0.0032)	(0.0032)	(0.0039)	(0.0038)
Distance to main market	-0.0001	-0.0006**	-0.0007**	0.0008***	-0.0006	-0.0001	-0.0006**	-0.0007**	0.0007**	-0.0006
	(0.0003)	(0.0003)	(0.0003)	(0.0003)	(0.0004)	(0.000)	(0.0003)	(0.0003)	(0.0003)	(0.0004)
Distance to agricultural extension	-0.0003	-0.0000	0.0006**	0.0003	-0.0005	-0.0004	-0.0001	0.0007**	0.0004	-0.0006
	(0.0003)	(0.0003)	(0.0003)	(0.0003)	(0.0004)	(0.0003)	(0.0003)	(0.0003)	(0.0003)	(0.0004)
Membership to farmer groups	-0.1742***	0.0186	0.0954*	0.0038	-0.0602	-0.1832***	0.0122	0.0951*	0.0030	-0.0459
	(0.0592)	(0.0567)	(0.0544)	(0.0551)	(0.0819)	(0.0597)	(0.0568)	(0.0547)	(0.0556)	(0.0818)
Number of relatives	0.0263***	0.0043	-0.0056	0.0495***	-0.0012	0.0273***	0.0039	-0.0068	0.0496***	-0.0022

in village	(0.0060)	(0.0058)	(0.0057)	(0.0058)	(0.0085)	(0.0061)	(0.0058)	(0.0058)	(0.0058)	(0.0086)
Reliance on	0.0026	-0.0107*	0.0124**	0.0134**	0.0365	0.0019	-0.0107**	0.0117**	0.0143**	0.0285
government support	(0.0050)	(0.0052)	(0.0056)	(0.0060)	(0.0468)	(0.0048)	(0.0050)	(0.0057)	(0.0066)	(0.0432)
Labor (male person	0.0001	-0.0026***	-0.0035***	0.0015***	0.0035***	0.0001	-0.0023***	-0.0034***	0.0015***	0.0036***
days)	(0.0004)	(0.0005)	(0.0004)	(0.0004)	(0.0005)	(0.0004)	(0.0005)	(0.0005)	(0.0003)	(0.0005)
Off-farm income	-0.1390***	-0.1628***	0.0649	-0.0905**	-0.0556	-0.1490***	-0.1641***	0.0568	-0.0905**	-0.0534
	(0.0437)	(0.0414)	(0.0442)	(0.0403)	(0.0577)	(0.0437)	(0.0416)	(0.0404)	(0.0405)	(0.0579)
Drought experience	2.4050***	0.4918***	-0.0014	0.6455***	0.2394***	2.4041***	0.4717***	0.2739***	0.6301***	0.2490***
	(0.1216)	(0.0520)	(0.0454)	(0.0489)	(0.0730)	(0.1192)	(0.0519)	(0.0422)	(0.0492)	(0.0731)
Credit constrained	-0.5229***	-0.0737*	-0.1969***	0.0370	-0.0915*	-0.5187***	-0.0742*	-0.2039***	0.0318	-0.1008*
	(0.0408)	(0.0392)	(0.0374)	(0.0379)	(0.0539)	(0.0409)	(0.0394)	(0.0376)	(0.0380)	(0.0538)
Assets										
TLU	-0.0237**	0.0039	0.0171*	-0.0159	-0.0701	-0.0239**	0.0035	0.0173*	-0.0166*	-0.0759***
	(0.0106)	(0.0100)	(0.0094)	(0.0101)	(0.0233)	(0.0105)	(0.0099)	(0.0092)	(0.0100)	(0.0238)
Information access										
Access to	0.0654	0.3453***	-0.0256	0.1016**	0.0097	0.0599	0.3512***	-0.0209	0.1027**	0.0155
government	(0.0491)	(0.0478)	(0.0458)	(0.0459)	(0.0684)	(0.0498)	(0.0481)	(0.0461)	(0.0463)	(0.0689)
extension										
Neighborhood	-0.0408	-0.3784***	-0.1051**	0.0890**	-0.1538**	-0.0266	-0.3758***	-0.0911**	0.1019**	-0.1613**
extension	(0.0459)	(0.0439)	(0.0421)	(0.0428)	(0.0667)	(0.0459)	(0.0440)	(0.0422)	(0.0427)	(0.0669)
Radio/TV extension	0.3490***	0.1170**	0.3145***	-0.1498***	-0.1112	0.3472***	0.1231**	0.3124***	-0.1648***	-0.1146
	(0.0513)	(0.0492)	(0.0471)	(0.0486)	(0.0739)	(0.0517)	(0.0495)	(0.0477)	(0.0490)	(0.0747)
Access to climate	0.2506***	0.2526***	0.3176***	0.7218***	-0.2986***	0.2389***	0.2562***	0.3138***	0.7146***	-0.3006***
information	(0.0532)	(0.0510)	(0.0482)	(0.0497)	(0.0807)	(0.0531)	(0.0510)	(0.0484)	(0.0498)	(0.0812)
Constant	-2.9037***	-0.7260***	-0.7737***	-1.5649***	-1.0615***	-2.9484***	-0.7179***	-0.7988***	-1.5797***	-0.0723***
	(0.1929)	(0.1458)	(0.1414)	(0.1438)	(0.1908)	(0.1943)	(0.1456)	(0.1427)	(0.1447)	(0.1919)

Likelihood ratio test of rho21= rho31= rho41= rho51= rho32= rho42= rho52= rho43= rho53= rho54= 0: Chi2 (10) =867.62 Prob>chi2=0.0000

Figures in parentheses are robust standard errors

* p< 0.1

** p<0.05

*** p< 0.01

Table 6: Simulated impacts of some variables on probability of adoption

	Drought Tolerant Crops ***DT***	% Change in Marginal Probability of Success	Early Planting ***EP***	% Change in Marginal Probability of Success	Pest and Disease Tolerance ***PDT***	% Change in Marginal Probability of Success	Crop Diversification ***CD***	% Change in Marginal Probability of Success	Soil and Water Conservation ***SWC***	% Change in Marginal Probability of Success
All variables at observed values	36.5		27.8		36.09		40.7		8.4	
Education at sample 7 years (c.f. 6 years)	47.4	29.9	27.9	0.3	36.6	1.3	41.0	0.8	8.4	0.43
Education set at 9 years (mid-secondary) c.f. 6 years	40.6	11.1	28.4	2.0	38.5	6.7	42.5	4.5	8.6	1.88
No Extension information on crops (c.f. 50%)	35.5	-2.9	22.6	-18.6	35.4	-2.0	39.0	-4.2	8.2	-2.23
Extension information on crops available to 100% (c.f 50%)	37.7	3.2	33.1	18.9	36.8	2.0	42.4	4.1	8.7	3.51
100% households credit constrained (c.f.	31.2	-14.5	27.1	-2.6	33.5	-7.1	40.0	-1.8	7.9	-6.22
0% credit constrained (c.f.)	47.5	30.0	29.1	4.7	41.1	13.8	41.0	0.8	9.4	12.01
Climate information not available	34.4	-5.8	25.2	-9.2	32.8	-9.1	33.0	-18.8	5.3	-37.30
Climate information 100% available	41.7	14.3	33.4	20.3	43.6	20.9	59.0	45.0	9.4	11.56

Table 7: Multivariate probit results for estimating determinants of adaptation to climate change for credit constrained households

Variable	Drought tolerant varieties ***DT***	Early planting ***EP***	Disease/ pest tolerant varieties ***PDT***	Crop diversification ***CD***	Practicing soil and water conservation measures ***SWC***
Information access					
Government extension	0.1130* (0.0584)	0.3258*** (0.0568)	-0.1026* (0.0541)	0.0822 (0.0544)	-0.3697*** (0.1341)
Neighborhood extension	-0.0781 (0.0554)	-0.3586*** (0.0531)	0.0009 (0.0508)	0.1789*** (0.0512)	0.4652*** (1125)
Radio/TV extension	0.3469*** (0.0603)	0.0257 (0.0579)	0.3860*** (0.0555)	-0.0000 (0.0562)	0.5669*** (0.1165)
Access to climate information	0.2636*** (0.0628)	0.1162* (0.0608)	0.1753*** (0.0573)	0.5717*** (0.0583)	0.0011 (0.1392)

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