Technology Innovations, Productivity and Production Risk Effects of Adopting Drought Tolerant Maize varieties in Rural Zambia

E. Amondo[1]; F. Simtowe[2]

1: International Maize and Wheat Improvement Center, Socioeconomics, Kenya, 2: International Maize and Wheat Improvement Center, Socioeconomics program, Kenya

Corresponding author email: emijete@gmail.com

Abstract:

This paper investigates the effects of adopting drought tolerant maize varieties (DTMVs) on farm productivity and risk exposure using a moment based approach on households growing maize in Zambia. First, second and third moments of farm production were used in estimations. The study applied an endogenous switching regression model that controls for both observed and unobserved sources of heterogeneity between adopters and non-adopters. The study revealed that the adoption of DTMVs increases maize yield, reduces yield variability and exposure to downside risk significantly. The adoption of DTMVs increased maize yield by 8% while reducing yield variance and the risk of crop failure by 35% and 27%, respectively. These results underscore the need for concerted efforts to scale-out the production of DTMVs for both maize productivity enhancement as well as for risk mitigation against climatic shocks.

Acknowledegment: This study was funded by the Drought Tolerant Maize for Africa (DTMA), a CIMMYT and IITA project funded by Bill & Melinda Gates Foundation. We also acknowledge the support of the survey coordinators, enumerators, Agricultural Research Institute (ZARI), Ministry of Agriculture and Livestock (MAL) and other implementing partners.

JEL Codes: Q16, O13

#2015

IAAE

Technology Innovations, Productivity and Production Risk Effects of Adopting Drought Tolerant Maize varieties in Rural Zambia.

Abstract

This paper investigates the effects of adopting drought tolerant maize varieties (DTMVs) on farm productivity and risk exposure using a moment based approach on households growing maize in Zambia. First, second and third moments of farm production were used in estimations. The study applied an endogenous switching regression model that controls for both observed and unobserved sources of heterogeneity between adopters and non-adopters. The study revealed that the adoption of DTMVs increases maize yield, reduces yield variability and exposure to downside risk significantly. The adoption of DTMVs increased maize yield by 8% while reducing yield variance and the risk of crop failure by 35% and 27%, respectively. These results underscore the need for concerted efforts to scale-out the production of DTMVs for both maize productivity enhancement as well as for risk mitigation against climatic shocks.

Keywords: *Drought, Drought tolerant maize varieties, Productivity, Risk, Endogenous switching regression*.

1. Introduction.

The majority of households in Sub-Saharan Africa (SSA) are more vulnerable to climate change by virtue of living in tropics and subtropics. Besides, agriculture is characterized by low productivity due to overdependence on unreliable rainfall, low level of input use, lack of infrastructure, lack of adequate knowledge on best management practices and frequent pests and diseases. Rain-fed staple crop production and raising livestock are inherently risky and investment and production decisions by farm households are, therefore, made within environments that are affected by risk (Yesuf, 2007). This however, has serious implications on productivity and food security at both household and national levels. Seemingly, the impacts of climate change on agriculture may likely be experienced by most people, notably the poor who are least able to adapt and this adds significantly to the development challenges of ensuring food security and reducing poverty (Jones and Thornton, 2003).

Drought risk has serious and complex implications on economic, social and environmental aspects of communities and is of greater concern (FAO, 2015; Monacelli *et al*., 2005). It is evident that drought occurs in both high and low rainfall areas and virtually all climate regimes causing diverse effects (World Meteorological Organization, 2006). Directly, drought affects production, lives, health, livelihoods, income, assets and infrastructure that contribute to food insecurity and poverty (Shiferaw *et al*., 2014). Indirect effects on reduced household welfare and environmental degradation have also significant implications (Shiferaw *et al*., 2014). In Sub-Saharan Africa (SSA), droughts and floods alone account for 80% of the loss of life and 70% of the economic losses (Bhavnani *et al*., 2008; Shiferaw *et al*., 2014; Hlalele *et al*., 2016). To note is that, continuous increase in population growth, poverty and inadequate policies are some of the reasons that have aggravated drought vulnerability and impacts in Africa (Tadesse, 1998; Shiferaw *et al*., 2014). As vulnerability to drought has increased in Africa and globally, greater attention has been directed to reducing the risks associated with its occurrence and if proper planning is done towards this, the decision makers will get an opportunity to relieve the most suffering at a least expense, increase self-reliance and reduce dependence on governments and donors (Monacelli et al., 2005).

Maize is the most important food and staple crop in SSA, consumed by 50 percent of the population and accounts for nearly half of the calories and proteins consumed by these people, yet, it is the most susceptible crop to drought (CGIAR). Maize demand in Africa (approximately 73% and 64% of the total demand in Eastern and Southern Africa and Western and Central Africa respectively) and consumption is on an increasing trend notwithstanding low yields due to several stresses, notably drought. Currently the average yield in Africa is low- 2 tons/hectare/year as compared to the worldwide average of approximately 5.5 tons/hectare/year (International Plant Biotechnology Outreach – VIB, 2017). Furthermore, there is a prediction that overall maize yield will decline for over 10 percent by 2050, meaning that developing countries would have to increase maize imports by 24 percent at an annual cost of US $30 billion (CGIAR; Nelson *et al*., 2009).

In Zambia, maize occupies a central position in its agricultural political economy as both the national staple food and primary smallholder crop (Chapoto *et al*., 2015). Just like other SSA, smallholder farmers (the majority of whom farm on less than two hectares of land) are the major producers - accounting for 79% of maize production in the country (JAICAF, 2008; Kassie et al, 2013; Government of Zambia, 2010). In 2006, Zambia was ranked 13th of the 51 maize producing African countries with 0.865 million tons (JAICAF, 2008). Maize occupied a significant area size of 1.36 million hectares in 2016 which is nearly a third of the total arable land (Republic of Zambia, 2016). Zambia enjoys over 80% of government spending on agriculture evidenced by high concentration on input and output subsidies (Farmer Input Support Program (FISP) and Food Reserve Agency (FRA) respectively (Chapoto *et al.*, 2015).

Despite the importance of maize in Zambia and the concerted efforts by government in the maize sector, the country continues to battle with low agricultural productivity and high rates of rural poverty - national average poverty rate of 54%, and rural poverty rate of 77% (Republic of Zambia, 2016). Among the nine Zambian provinces, the Eastern province is the largest maize producer, followed by the Southern and Central provinces (JAICAF, 2008). The fluctuating maize production trend in Zambia as depicted in Figure 1 is partly due to climate change – particularly drought being experienced by small-scale farmers. According to Government of the Republic of Zambia (2010), Zambian communities are vulnerable to climatic hazards (such as drought, flooding, extreme temperatures and prolonged dry spells) since they rely solely on rain-fed agriculture and majority of farmers lack the capacity, resources and financial assistance to adapt to and overcome worsening climatic conditions. The Zambia NAPA highlighted that the area suitable for staple crop (such as maize) production under rain-fed conditions is likely to decline by 80% by 2100 as a result of climate change (Government of Zambia, 2010). Indeed, it has been established that within the last 20 years, prolonged dry spells and shorter rainfall seasons have reduced maize yields to only 40% of the long-term average (Government of Zambia, 2010).

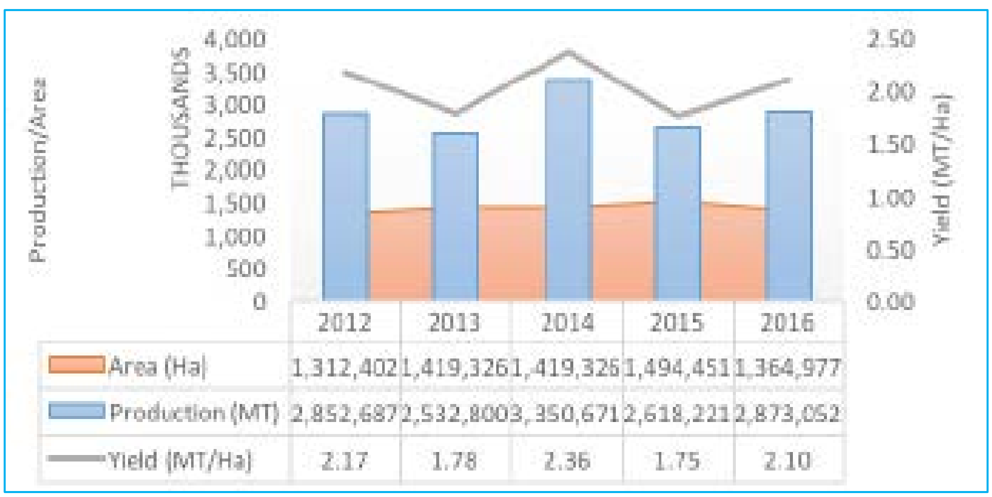

Figure 1: Maize production trends in Zambia
Source: Crop Forecast Survey Data, 2012-2016

Dercon (2004) and Fisher *et al* (2015) indicate that African households are not helpless in the face of variable and changing climates since the different strategies to adapt and cope with risk are already available and being used. Nonetheless, some of these methods are insufficient for protecting livelihoods in drought prone regions of SSA (Shiferaw *et al*., 2014; Fisher *et al*., 2015). One of the effective, innovative adaptation strategy (drought tolerant maize varieties - DTMVs) that addresses drought stress in African production systems have been developed since 2006 and deployed by the International Maize and Wheat Improvement Center (CIMMYT) in collaboration with other CGIAR centers, National Research Institution and other private seed producers. The drought-tolerant well-adapted maize hybrids and open-pollinated varieties (over 200 released) are designed to help farmers across over 13 countries in Eastern, West and Southern Africa, and beyond, cope with drought constraint in maize farming (Shiferaw, 2014, Fisher *et al*., 2015; Wossen *et a.l*, 2017). These varieties help in increasing farmers' maize yield by at-least one ton per hectare under moderate drought and with 20-30 percent increase over farmers' current yields and also provides insurance against the risk of maize farming (CIMMYT, DTMA; Shiferaw *et al*., 2014)[1]. The DTMVs are not only tolerant to drought but also possess desirable traits resistance to major diseases (e.g. maize streak virus, Turcicum leaf blight, and gray leaf spot), superior milling or cooking quality, have high levels of lysine and tryptophan and are better nitrogen use efficiency (CIMMYT, DTMA[2]; Fisher *et al*., 2015; Wossen *et al*., 2017).

Production and consumption risks are known to play a critical role in the choice and use of production inputs and adoption of new farm technologies in countries where insurance and credit markets are thin or missing (Yesuf *et al*., 2009; Juma *et al.*, 2009). Antle (1983, 1987); Dercon (2004) and Kassie *et al* (2008) augment that production risks plays a key role in agricultural production decision (particularly in input choices) and contribute toward worsening social welfare in the absence of mechanisms that serve to minimize its downside effects. Proper knowledge on the link between production risk exposure and technology adoption decisions is requisite to successful scaling up of farm technologies across poor farm households and reduction of food insecurity and rural poverty in many countries (Juma *et al.*, 2009). Likewise, farming households are/need to be cautious on the choice of technology since some farm technologies could increase production risks either by increasing yield variability or increasing probabilities of crop (Yesuf *et al*., 2009).

In view of the above discussion, the objective of this paper is to provide empirical evidence on the productivity and risk implications of adopting DTMVs in the rural Zambia, using Antle's moment-based approach (mean yield, variance and skewness). The analysis on the impact will be done by use of endogenous switching regression approach to control for both observed and unobserved sources of heterogeneity. The rest of the paper is organized as follows. In section two, we present a brief review of the literature on farm technology adoption and impact. Section three we outline data sources, sampling procedure and descriptive statistics. Section four presents and discusses the econometric results. Conclusion and policy implications are stipulated in section five.

[1] Available at http://dtma.cimmyt.org/index.php/about/background
[2] Available at http://dtma.cimmyt.org/index.php/about/background

2. Literature Review

Literature on agricultural technology adoption studies reveal that productivity and risk implications of farm technology adoption vary by technology type and this plays a non-trivial role in farmer's adoption decision especially in low-income, rain-fed agriculture (Yesuf *et al*., 2009; Kassie *et al*., 2008; Juma *et al.,* 2009). Adoption of new farm technology could increase production risk either by increasing yield variability or increasing probabilities of crop failure and vice versa is true (Yesuf *et al*., 2009). Past studies indicate that DTMVs not only increases yield or reduce the vulnerability of farm households to drought related harvest failure, but also positive impacts impacts in providing insurance against the risk of maize farming as well as reducing yield variability. Shiferaw et al (2015) points out that DT is one of the ex-ante drought risk coping strategies –reducing risk. Furthermore, DT varieties helps households lessen the need for harmful post-failure coping strategies like liquidating productive assets such as livestock or land in exchange for food, default on loans, disengaging children from school and minimizing food consumption amidst severe food security and livelihoods stresses in order to survive (Hansen *et al.,* 2004; Shiferaw, 2014; Fisher et al., 2015).

Juma *et al* (2009) assessment on production risks and farm technology adoption among smallholder farmers revealed that, among others, yield variability and the risk of crop failures indeed affect technology adoption decisions in low-income, rain-fed agriculture though the direction and magnitude of effects depend on the farm technology under consideration. Their study further denotes that productivity gains are necessary, but not sufficient, conditions to attract farmers to adopt new technologies and agricultural innovations. This is evidenced by the fact that poor farm households in rain-fed and risky production environments are reluctant to adopt new farm technologies with potential production gain because, at the same time, they involve enormous downside risks (Juma *et al*, 2009).

Similarly, a study conducted by Kassie *et al* (2008) using two-year cross-sectional plot level data on the role of production risk on sustainable land - management technology adoption using moment based approach unveiled that while expected return (as measured by the first central moment) had a positive significant impact on both chemical fertilizer (adoption and intensity) and conservation adoption, production risks (variance and crop failure as measured by second and third central moments, respectively) had significant impact on only fertilizer adoption and extent of adoption and no statistical significance impact on adoption of conservation technology in Ethiopia. On the other hand, Yesuf *et al* (2009) reports that chemical fertilizer adoption reduced yield variability, but increased the risk of crop failure while adoption of soil and water conservation technology had no impact on yield variability, but reduced the downside risk of crop failure. The implications from these studies is that the impact of production risk varies by technology type and that mechanisms that reduce variance of return and exposure to downside risk, increase productivity and insure that food production would not fall below some threshold level are desirable in the fertilizer adoption, adoption of other improved technologies and reduction of poverty.

Konstandini *et al* (2013) using geo-referenced production data at the regional and household levels from both on-station (experiment station) and on-farm trial data in 13 East, South and West Africa countries, reports that, subsequent adoption of DTM may generate substantial benefits to both producers and consumers and DTMVs may be an effective tool for reducing house-hold risk, especially for the poor who face high drought risk and are highly dependent on cereal production. They observe that risk benefits appear to be more important in more drought prone areas and the role of DTM in variance reduction accounts for a significant share of total benefits. Thus, variance reductions do not only contribute a considerable share of total benefits, but also offer higher benefits in marginal production areas with poorer households thus contributing significantly towards poverty reduction. They further suggest that policies and investments that set up the right infrastructure for the production and dissemination of DTM may prove to be very beneficial in both the short and long term.

Using household and plot level data from rural Nigeria, Wossen *et al* (2017) explores the impacts of DTMVs on productivity, welfare and risk exposure. Since there is wider acceptance of the significant role of DTMVs in productivity enhancing and risk reduction, Wossen et al (2017) found out that adoption of DTMVs indeed increased maize yields by 13% and reduced the level of variance by 53% and downside risk exposure by 81% among adopters. As a result, there was a reduction of 13% in the incidences of poverty and 84% in the probability of food scarcity among adopters. From this study, it is inferred that, interventions against drought stress through genetic improvements and the subsequent adoption of these improved technologies will have a paramount role to play in terms of enhancing food security and reducing farmers' exposure to drought risk (Wossen *et al*., 2017).

3. Data Sources and Sampling.

Data sources

Household survey data collected by International Maize and Wheat Improvement Center (CIMMYT) from November 2015 to December 2015 in three maize producing provinces (Eastern, Southern and Copperbelt) of rural Zambia was used in this study. The survey covered a representative sample of 1100 households randomly selected in 11 districts using a three-stage sampling procedure. The sampling strategy ensured selection of equal number of households in each district (100 households in each) sampled. The stages involved identification of camps, selection of villages and subsequent sampling and selection of households for survey interviews. The districts covered include; Masaiti Chadiza, Chipata, Katete, Lundazi, Petauke, Choma, Kalome Monze, Siavonga and Sinazongwe. To successfully implement the DTMASS survey, the Zambia Agricultural Research Institute (ZARI), Ministry of Agriculture and Livestock (MAL) and village headmen and camp agricultural committee chairpersons provided support to identify areas, camps and households for the survey. A structured household questionnaire was used to collect data using face-to-face interviews technique, administered by well-trained enumerators after the pre-test exercise. The survey instrument was well designed - consisted of 14 modules that captured detailed information on a range of variables on household socio-economic information, farm plot characteristics, maize plot characteristics, management, input use, labor, varieties grown, production and utilization, livestock, farm tools, transport and communication assets, drought risk perception and adjustments, DTMVs awareness and adoption, Social capital and market access, access to information and credit, food security and maize self-sufficiency. However, only few modules relevant to the objectives of this study were used in this study.

Descriptive statistics.

Outcome indicators

The major outcome indicator was maize yield. The distribution of maize yield between DT adopters and non-adopters using kernel estimates in Figure 2(a) and 2(b) reveal that the average maize yield was slightly higher among DT adopters in both cases, followed by improved non- DT seed adopters and lastly those planting local seed registered lower yields. Besides, a more left-skewed (negative) distribution on non-adopters of DT and improved seed adopters as compared to DT adopters is evident in Figure 2(b) signifying that the skewness of maize yield was lower among adopters. The Kolmogorov-Smirnov test for equality of distribution functions demonstrated that the two distributions between DT adopters and non-adopters are different.

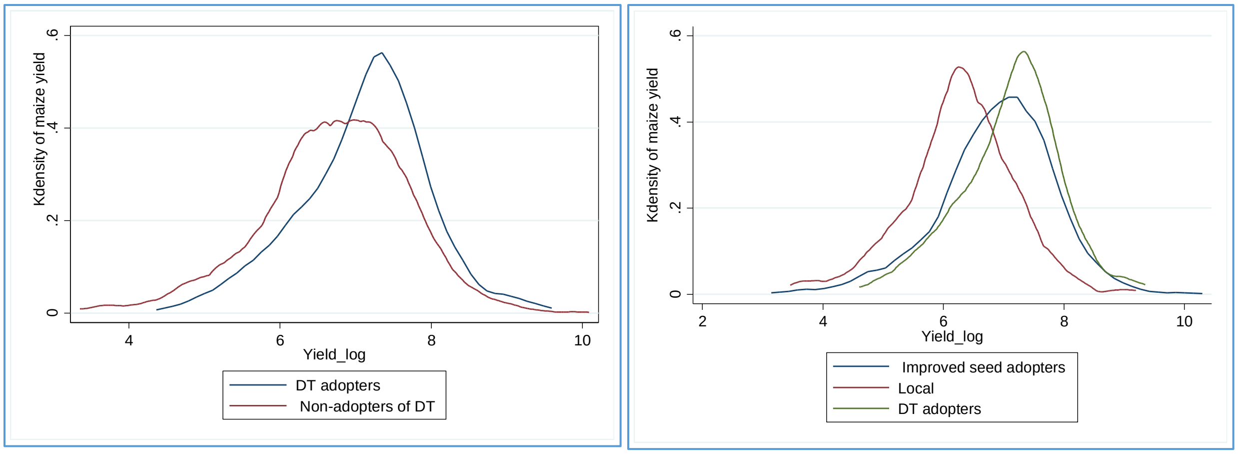

Figure 2: Distribution of maize yield among DT adopters and non- adopters (a); DT adopters, improved non-DT seed adopters and local seed growers (b).

Socio-economic and plot variables.

Table 1 presents the summary descriptive statistics for all sampled households – adopters and non-adopters of DTMVs. These household and plot level variables were also the repressors included in the OLS and endogenous switching regression model since they are assumed to affect farmers decisions to adopt as well as their productivity and behavior towards production risk. Results indicate that 20 percent of households had adopted at-least one drought tolerant maize variety in 2015 with Eastern and Southern province contributing a largest share of the total - 9.7% and 7.2% respectively.

Only 19% of households were headed by women. As depicted in Table 1 households were relatively large in size consisting of an average of 7 members per household with significant statistical differences between adopters and non-adopters. The mean age of household heads was 47 years with an average farm size of 4ha where maize occupied a significant share of 1.8 ha (approximately 45%) of the average farm land. With regards to maize area, high positive statistical significant differences between the two groups was observed. Households typically owned houses whose wall material was made using either wood & mud, reeds& bamboo, cement &stones, blocks or bricks. Livestock keeping was also a key economic activity with households having an average of five Tropical Livestock Units.

Table 1: Descriptive statistics by adoption status of DTMVs

Variable	Full Sample (N=1097)	Adopters (N=221)	Non-adopters (N=876)	Mean difference
Household size	6.9	7.2	6.9	0.39*
Age of household head (years)	46.5	46.3	46.5	-0.2
Sex (1= male, 0= female)	0.81	0.84	0.81	0.039
Education of household head	6.06	6.66	5.9	0.76**
Distance to the nearest maize seed market (min)	70	80	68	12**
Wall material - wood & mud, reeds& bamboo, cement &stones, blocks or bricks (1=yes)	0.72	0.77	0.70	0.07**
TLU	4.5	5.1	4.4	0.67
Farm size (ha)	4.04	4.27	3.99	0.28
Maize area (ha)	1.8	2.2	1.7	0.5***
Dry spell in 2015 (1=yes)	0.77	0.8	0.76	0.04
Obtain information on rainfall & weather (1=yes)	0.7	0.73	0.7	0.03
Obtain information on new maize varieties (1=yes)	0.44	0.43	0.44	-0.01
Member in informal association (1=yes)	0.88	0.93	0.87	0.06***
Labor (Man-days)	85	101.5	81.3	20.2*
Hired labor use (1=yes)	0.58	0.7	0.56	0.14***
Inorganic fertilizer use (1=yes)	0.8	0.94	0.76	0.18***
D-Compound fertilizer (kgs)	162	254	139	115***
Urea (kgs)	158	250	135	114***
Pesticide use (1=yes)	0.11	0.15	0.1	0.05**
Cover crop use (1=yes)	0.16	0.15	0.16	-0.01
Intercropping (1=yes)	0.67	0.62	0.68	-0.06
Good soil (1=yes)	0.3	0.36	0.29	0.07**
Fair Soil (1=yes)	0.4	0.45	0.39	0.06
Poor soil (1=yes)	0.44	0.42	0.45	-0.03
Male owned plots (1=yes)	0.73	0.78	0.72	0.06*
Female owned plots (1=yes)	0.23	0.19	0.24	-0.05*
Joint owned plots (1=yes(	0.022	0.027	0.02	0.007
Maize yield Kg/ha	1374	1696	1292	403.8***
Maize grain sold (kgs)	929	1817	705	1111***
Maize self-sufficient (1=yes)	0.7	0.78	0.68	0.10***

*** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

Maize seed market was relatively far since households had to travel quite a distance spending on average 70 minutes one way. Adopters travelled more distance as compared to non-adopters. Nearly 77% of households reported to have experienced drought in 2015, with more adopters reporting drought as compared to non-adopters. This results indicates a correlation between occurrence of drought and adoption of DT. Concerning social capital, majority of households (88%) were members in at-least one informal association. Furthermore, high proportion of adopters were members of groups as compared to non-adopters and the difference was significant. Multiplicity of benefits in social networks notably access to information and influence partly explains why more adopters were in groups. On information access, most households (70%) obtained information on weather/rainfall. However, only few households (44%) had access to information regarding new maize varieties. This result evidently suggests that there was information gap on new maize varieties, since information was not readily available to farmers in both categories. The implications is that there is need for a more concerted effort on awareness by different stakeholders in maize value chain, both private and public.

On plot variables and input use, results indicate that male owned majority of plots (73%). Use of chemical fertilizers was good with 80% of households using in-organic fertilizers at-least in one of their plots. Adopters used significantly higher amount of fertilizers as compared to non-adopters. The mean average amount of planting fertilizer (D-compound) used by a household was 162kgs while the topdressing fertilizer (urea) was 158kgs. Fertilizer application rate for all fertilizers applied was 227 kg/ha. This figure was not very far from the nationally recommended application rate of 200 kilograms of basal fertilizer (Compound D, 10-20-10 NPK) and 200 kilograms of top dressing fertilizer (Urea, 46-0-0) per hectare of maize. Increase in fertilizer use in Zambia could be attributed to the government fertilizer subsidy programs (FISP) and while this is expected to have a positive yield response and increased profitability, the average yields registered by interviewed households are still lower (1.3 tons/ha) than the worldwide average of approximately 5.5 tons/hectare/year. This result indicate that fertilizer is important in soil fertility management and crop production but if used solely, in a wrong manner and in absence of other good agronomics practices, achievement of better yields is elusive. To supplement to this notion, a study conducted by Z. Xu *et al* (2009) found out that farmers' ability to acquire fertilizer in a timely manner has a strong positive effect on maize yield response to fertilizer. However, it is noted that in Zambia subsidized fertilizers under government programs has often been distributed late (Z. Xu *et al*., 2009).

Generally, labor use and hired labor was high among adopters (102 man-days and 70% respectively). Intercropping was a common practice, employed by 67% of households. Pesticide use and cover crops were used on a minimal extent by 11% and 16% of households respectively.

4. Empirical results

OLS Results.

We used a generalized linear model (OLS) to determine the effect of adoption of DTMVs on mean yield, variance and skewness (downside risk exposure). Di Falco *et al* (2010) points out that OLS is the simplest approach to investigate the effect of adaptation on food production consists in estimating an OLS model of food production that includes a dummy variable equal to 1 if the farm household adapted, 0 otherwise. Control variables used in this model included household and farm characteristics that were assumed to affect farmer's adoption decision and also productivity, food security and poverty. These variables include; household size, age, gender, TLU, membership in different social groups, occurrence of drought shocks in 2015, one way travel time to the nearest input markets, information access on new maize, hired labor use, total quantity of chemical fertilizers used, pesticide use, intercropping, plot soil fertility status and plot ownership.

Table 2: OLS estimates of the effects of adoption on mean, variance and skewness of maize yields

	Average yield	Yield variance	Yield skewness
DT adoption	0.202***	- 0.144	0.164**
	(0.072)	(0.166)	(0.081)
Other controls	Yes	Yes	Yes
Location dummies	No	No	No
N	973	973	973

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

It was observed that location dummies had an effect on our outcome variables since statistical significance and effect reduced when location dummies were incorporated in the model. In absence of location dummies, OLS results in Table 2 indicated that DT adoption had a positive statistical significant effect on maize productivity and skewness, with DT adoption increasing maize yields by 20% and reducing exposure to downside risk by approximately 16%. These results illustrate that adoption of DT can serve as productivity enhancing as well as insurance for farmers by increasing yield and minimizing the risk of crop failure. Although the results indicate that adoption of DT reduced the variability of maize yield, there was no statistical significance.

As much as OLS results shows that there was increase in maize yield and reduction in risk for the farm households that adopted DT as compared to non-adopters, these results are not reliable for it is widely known that OLS yields biased and inconsistent estimates. In this case, the approach assumes that adoption of DT is exogenously determined while it is a potentially endogenous variable. Moreover, Di Falco *et al* (2010) stipulates that OLS do not explicitly account for potential structural differences between the production function of farmers who adapted to climate change and the production function of farmers that did not adapt.

Endogenous switching regression (ESR) results.

In order to tackle the limitations identified with OLS above, ESR model that accounts for both observable and unobserved sources of heterogeneity between adopters and non-adopted was further used in this study to compare the distribution of maize mean yield, variance and skewness with and without DT adoption. We adopted one of the most efficient estimation method (the *movestay* command) recommended by Lokshin and Sajaia (2004) due to the fact that it enables implementation of the full information ML method (FIML) to simultaneously estimate binary and continuous parts of the model in order to yield 2 consistent standard errors. This counterfactual analysis method was used to investigate and enabled comparisons of the expected outcome indicators under the actual and counterfactual cases that the farm household adopted DT or not. Calculations on treatment and heterogeneity effects carried out enabled understanding of the differences in maize productivity and risk reduction between farm households that adopted DT maize (ATT) and those that did not adopt DT maize (ATU).

Table 3: ESR estimates of the effect of adoption on mean, variance and skewness of maize yields

Outcome variables	Household type and treatment effect	Decision stage		Effect on adoption	Change (%)
		To Adopt	Not to adopt		
Average maize yield	DT Adopters (ATT)	7.09	6.57	0.52***	8
	Non-adopters (ATU)	8.29	6.75	1.54***	23
	Heterogeneity effect	-1.2	-0.18	-1.02	
Average Variance	ATT	12.57	19.27	-6.7***	-35
	ATU	12.73	12.82	-0.09***	-1
	Heterogeneity effect	-0.16	6.45	-6.61	
Average skewness (downside risk exposure)	ATT	14.64	11.55	3.09***	27
	ATU	12.69	14.31	-1.61***	-11
	Heterogeneity effect	1.95	-2.76	4.71	

*** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

The results in Table 3 unveiled that adoption of DT maize increased average yield significantly by 8%. This implies that maize yield among DT adopters would have declined by 8% if they not adopted DT maize varieties. Likewise, the maize yield of non-adopters would have increased significantly by 23% if they had adopted DT maize varieties. ATT and ATU results were both positive and significant on average maize yield and this implies that indeed adoption of DT maize significantly increases maize productivity. However, a negative transitional heterogeneity effect reveal that the effect is smaller for the farm household that actually did adopt with respect to those that did not adopt DT. Considering that over three quarters of the sampled farmers were still non-adopters of DTMVs (where productivity would have increased by 23% if they had adopted), continuous concerted efforts on awareness and dissemination strategies of DTMVs by private and public institutions will greatly increase food security and resilience to drought in Zambia.

With regards to variance and skewness of maize yield, ATT and ATU results indicate that adoption significantly reduced yield variability and exposure to downside risk (crop failure). Particularly, adoption of DT maize reduced the variability of maize yield by 35%, in other words, the yield variance encountered by DT adopters would have increased by 35% if they had not adopted DT maize varieties in their farming systems. On crop failure, adopters of DT maize varieties would have increased by 3.09 units, equivalent to 27% if they had not embraced the DTMVs. The transitional heterogeneity effects on variance and skewness were negative and positive respectively.

ESR results on maize productivity and production risk factors (both yield variance and downside risk), deduce that, DTMVs have a win-win outcome because they do not only boost yield but also risk reducing. Our results on effect of DT maize on maize productivity and risk were consistent with Wossen *et al* (2017) who found out that the adoption increased maize yield increased by 13% and reduced variance by 53%. Though the effect on downside risk as reported by them was 81% as compared to 27% in this study, the effect was significant and on course. Since it is widely recognized that risk and risk aversion influences management decisions of farmers and Hardaker *et al* (2015) affirms that people who are risk averse maybe willing to forgo some expected output for reduction in risk, the rate of acceptable trade-off depending on how risk averse that person is, institutions involved in agricultural technology dissemination should consider including DTMVs in their input packages and be on the forefront to help farmers in building resilience to drought as well as improve food security and poverty reduction.

5. Conclusions and Implications.

In this article, we analyzed the effects of adopting DTMVs on productivity and production risks factors using household and farm level data from rural Zambia. Using endogenous switching regression model that accounts for both observable and unobservable factors that influence the decision to adapt or not to adapt we observed significant yield gains and production risk (as measured by the variability of return and crop failure) reduction in DTMVs adopters. Projections indicate that current non-adopters - the counterfactual case that they adopted DTMVs, would have realized much higher yield gains as compared to farm households that actually adopted DTMVs. Specifically, the yield of adopters would have declined by 8% if they had not adopted while for non-adopters, their yield would have increased by 23% if they adopted DTMVs. Furthermore, the level of variance and downside risk exposure among adopters could have increased by 35% and 25% respectively if they had not adopted.

These findings have some policy implications. As much as there is existence of some beneficial technological, policy and institutional options for effective drought management in SSA, the role of risks, notably, in technological options is key for effective agricultural policies. Considering the risk averse nature of most farmers and some degree of risk associated with most technologies, design and promotion of effective drought adaptation strategies that addresses both yield gains and risk reduction in terms of yield variability and downside risk (probability of crop failure) should be done. When such technologies are available, farmers will be motivated and will embrace the technologies and as a result high adoption rates will be observed rapidly due to successful scale out and thus improved food security and welfare of farmers in the low income countries in the face of changing climate change.

6. References.

Antle, J.M (1983); Testing for Stochastic Structure of Production: A Flexible Moment-Based Approach; *Journal of Business and Economic Statistics* 1(3); 192–201.

Antle, J.M (1987); Econometric Estimation of Producers' Risk Attitudes; *Journal of Agricultural Economics* 69 (3); 509-522.

Chapoto, A., Zulu-Mbata, O., Hoffman, B.D., Kabaghe,C., Sitko,N., Kuteya, A and Zulu, B (2015); The Politics of Maize in Zambia: Who holds the Keys to Change the Status Quo? *Working Paper No. 99*; Indaba Agricultural Policy Research Institute (IAPRI).

Dercon, S (2004); Growth and Shocks; Evidence from Rural Ethiopia; *Journal of Development Economics* 74(2); 309–329.

Di Falco, S., Veronesi, M and Yesuf, M (2010); Does Adaptation to Climate Change Provide Food Security? A Micro-Perspective from Ethiopia; Centre for Climate Change Economics and Policy Working Paper No. 22.

Food and Agricultural Organizations of the United Nations (FAO, 2015); Drought Risk Management: A Collaborative Program to Build Greater Resilience to Drought and to Mitigate its Scourges on Societies and Economies.

Government of Zambia (2010); Adaptations to the Effects of Drought and Climate Change in Agro-ecological regions I and II in Zambia.

Hardaker, J.B., Lien, G., Anderson, J.R and Huirne, R.B.M (2015); Coping with Risk in Agriculture*; 3rd Edition; Applied Decision Analysis.*

Hlalele, B.M, Mokhatle, I.M and Motlogeloa R.T (2016); Assessing Economic Impacts of Agricultural Drought: A Case of Thaba Nchu, South Africa; *Journal of Earth Science and Climate Change 2016*, 7:1 http://dx.doi.org/10.4172/2157-7617.1000327.

International Plant Biotechnology Outreach – VIB (2017); Maize in Africa; *Fact Series.*

Japan Association for International Collaboration of Agriculture and Forestry (JAICAF, 2008); The Maize in Zambia and Malawi

Jones, P.G and Thornton, P.K (2003); The Potential Impacts of Climate Change on Maize Production in Africa and Latin America in 2055; Journal of Global Environmental Change 13; 51–59.

Juma, M., Nyangena, W and Yesuf, Y (2009); Production Risk and Farm Technology Adoption in Rain-Fed, Semi-Arid Lands of Kenya; *Environment for Development Discussion Paper Series*.

Kassie, G., Langyintuo, A., Erenstein, O., Maleni, D., Gwara,S and Abate, T (2013); Drought Risk and Maize Production In Southern Africa; *Journal of Asian Scientific Research*, 3(10); 956-973.

Kassie, M., Yesuf, M and Köhlin, G (2008); The Role of Production Risk in Sustainable Land-Management Technology Adoption in the Ethiopian Highlands; *Environment for Development Discussion Paper Series*.

Kostandini, G., Abdoulaye, T., Erenstein, O., Sonder, K., Guo, Z, Setimela, P and Menkir, A (2015); Potential Impacts of Drought Tolerant Maize: New Evidence from Farm-trials in Eastern and Southern Africa; *Contributed Paper prepared for presentation at the 89th Annual Conference of the Agricultural Economics Society*, University of Warwick, England 13 - 15 April 2015.

Kostandini, G., La Rovere, R., Abdoulaye, T (2013); Potential Impacts of Increasing Average Yields and Reducing Maize Yield Variability in Africa; *Journal of Food Policy* 43; 213-226.

Koundouri, P., Nauges, C., Vangelis, T (2006); Technology Adoption under Production Uncertainty: Theory and Application to Irrigation Technology; *Journal of Agriculture Economics*; 88 (3).

Lokshin, M and Sajaia, Z (2011); Impact of Interventions on Discrete Outcomes: Maximum Likelihood Estimation of the Binary Choice Models with Binary Endogenous Regressors; *The Stata Journal* 11(3); 368–385

Monacelli, G., Gallucio, M. C. & Abbafati, M (2005); Drought Assessment and Forecasting, Prochoice, Czech Republic: World Meteorological Organization.

Nelson, G.C., Rosegrant,M.W., Koo,J., Robertson,R., Sulser,T., Zhu,T., Ringler, C., Msangi, S., Palazzo, A., Batka,M., Magalhaes,M., Valmonte-Santos, R., Ewing, M and Lee, D (2009); Climate Change - Impact on Agriculture and Costs of Adaptation; *IFPRI Food Policy Report*.

Republic of Zambia - Central Statistical Office (2016); 2015 Living Conditions Monitoring Survey Report.

Shiferaw, B., Tesfaye, K., Kassie, M., Abate, T., Prasanna, B.M and Menkir, A (2014); Managing Vulnerability to Drought and Enhancing Livelihood Resilience in Sub-Saharan Africa; Technological, Institutional and Policy Options; *Journal of Weather and Climate Extremes* (3); 67–79.

Tadesse,T (1998); Improving Drought Management and Planning through Better Monitoring in Africa; *Drought Network News*(1994–2001), Paper 81.

World Meteorological Organization (2006): Drought Monitoring and Early Warning: Concepts, Progress and Future Challenges; WMO-No. 1006; ISBN 92-63-11006-9

Wossen , T., Abdoulaye,T., Alene, A., Feleke, S., Menkir, A and Manyong, V (2017); Measuring the Impacts of Adaptation Strategies to Drought Stress: The Case of Drought Tolerant Maize Varieties; *Journal of Environmental Management* 203; 106-113.

Yesuf, M (2007); Risk Aversion in Low Income Countries: Experimental Evidence from Ethiopia; *IFPRI Discussion Paper 00715*.

Yesuf, M., Kassie, M and Köhlin, G (2009); Risk Implications of Farm Technology Adoption in the Ethiopian Highlands; *Working Papers In Economics No 404*; School of Business, Economics and Law at University of Gothenburg.

Z.Xu., Guan, Z., Jayne, T.S and Black, R (2009); Factors Influencing the Profitability of Fertilizer Use on Maize in Zambia; *Policy Synthesis Food Security Research Project – Zambia*.