Willingness to pay for Drought Tolerance (DT) in Maize in Communal Areas of Zimbabwe

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Abstract

This study aimed at estimating the implicit prices farmers are willing to pay (WTP) for maize traits with deliberate focus on drought tolerance. Using choice experiment, we generated 12600 observations from a random sample of 1400 households in communal areas within 14 districts of Zimbabwe. Taste parameters and heterogeneities (scale and residual taste) were estimated using the generalized multinomial logit model (G-MNL) and its different versions. Drought tolerance, grain yield, large grain size, covered cob tip, big cob and semi flint texture were the most preferred traits by rural Zimbabweans. The WTP values were estimated using the WTP space approach. Sample farmers are, for example, willing to pay a premium for drought tolerance that is 1.75 times the amount they are willing to pay for an increase of 1 ton in grain yield per acre, 8.3 times the value they attach for a change from small to big cob size, and 14.7 times the willingness to pay for semi-flint texture over dent texture of maize. The uncertainty that DT might not be appealing to poor farmers as much as some other technologies can only be cleared only if the promotion of DT materials is done in the right manner and to the right farm community. Innovative ways of promoting DT maize vis-à-vis creating awareness in contextual understanding of drought and drought risk shall be employed to enhance adoption of new DT maize varieties by risk prone farming communities. Given the high level of rural literacy and the high rate of adoption of improved maize in Zimbabwe, trait based promotion and marketing of varieties would be the right strategy.

Introduction

Maize plays a crucial role in the livelihoods of people in Sub-Saharan Africa. It is the staple food crop for majority of the population in the continent and nearly to all in southern Africa, serving as source of 40-50% of the calorie consumed by the poor (Smale et al., 2011). Being a strategic crop in the region, maize has been subjected to different academic and political interests for more than half a century. However, there have been tremendous achievements in maize research in developing new and widely adapted varieties (Byerlee and Eicher, 1997, Smale, 1995, Smale and Jayne, 2003). Despite the success stories around maize, poverty and food insecurity in the maize based livelihood systems of southern Africa remain deep-rooted. In fact, since 1970, per capita grain production in Sub-Saharan Africa (SSA) has declined by more than 10 percent (Minot, 2008). The key challenges that constrain agricultural productivity in southern Africa are drought, pests and diseases of plants and livestock, soil degradation, unaffordability of farm inputs, lack of financial resources, erratic rainfall, and flooding (Kassie et al., 2012).

Drought is a widespread phenomenon across large areas of SSA with an estimated 22% of mid-altitude/subtropical and 25% of lowland tropical maize growing regions affected annually due to inadequate water supply during the growing season (Chambers, 1989). Yield losses are quite high in tropical countries that rely on a relatively unpredictable rainy season for crop growth. Past experience has demonstrated that the use of new varieties alongside improved management options can offset yield losses by up to 40% (Hendrix and Glaser, 2007). Specifically, drought and heat tolerant crops will play an increasingly important part in adapting to this variation and to the long term underlying trend towards a hotter and probably drier production environment. So goes the argument that given the scarcity of water and its cardinal role in crop production, it follows that tolerance to drought and efficient water usage should be assigned the highest priority in developing future crops. Drought tolerance trait in maize is of enormous global importance, which virtually no crop or farmer in the world can afford to be without (Lybbert and Bell, 2010, Edmeades, 2008); using water at current rates when the world will have to support 9 billion people or more in 2050, is simply not sustainable (Lobell et al., 2008).

There are a number of global efforts that aim at developing maize germplasm with drought tolerance trait embedded in them (Lybbert and Bell, 2010). In Sub-Saharan Africa, the main initiative in this regard is the drought tolerant maize for Africa (DTMA) project being implemented since 2006 by the International Maize and Wheat Improvement Center (CIMMYT), International Institute for Tropical Agriculture (IITA) and National Research/Extension Institutions of 13 countries in eastern, southern and western Africa. It is reported that the varieties being developed by the initiative give 20-30% more yield in

farmers' fields than current varieties available to smallholder farmers (La Rovere et al., 2010). The varieties developed by DTMA provide farmers with better yields than leading commercial varieties under moderate drought conditions, and have competitive or even better yield potential when rains are good.

The impact of the varieties and related technologies being developed is apparently dependent on the extent of dissemination and use by the farmers. Farmers' adoption decisions for improved maize varieties are essentially governed by their willingness to pay for the different traits. While many stakeholders including seed companies play an important role in the deployment of the improved varieties, they need varieties with the traits desired by farmers. The best way for assessing the effective demand for the desired traits is to quantify the implicit prices of the desired traits. Hence, this study was designed to understand the preferences for the different traits of maize and to estimate the implicit prices of preferred traits with deliberate focus on drought tolerance in the drought prone communal areas of Zimbabwe.

There are quite a number of studies that estimated the willingness to pay for traits of crops over the last 10 years (Carlsson et al., 2007, Poudel and Johnsen, 2009, Smith and Fennessy, 2011, Wale and Yalew, 2007). There are however very limited studies that employed the theoretically and behaviorally plausible method of choice experiment to do so (Asrat et al., 2010, Blazy et al., 2011). However, this is the first study to the best of our knowledge in sub Saharan Africa (SSA) to apply choice experiments with an econometric framework that allows estimation of willingness to pay (WTP) values in WTP space using the generalized multinomial logit model (G-MNL) developed by (Fiebig et al., 2010). This estimation framework accommodates both scale and residual taste heterogeneities.

This research will contribute in different ways to the current state of knowledge. First, it employs the most advanced estimation procedure to estimate the taste parameters and scale and residual taste heterogeneities. . Second, it estimates the implicit prices of preferred maize traits in the WTP space framework. Third, this study presents the first empirical estimation of the WTP for the drought tolerance trait, which is the most important trait in selecting maize varieties for production in southern Africa (Chikobvu et al., 2010, Kassie et al., 2012).

Maize in Zimbabwe

Zimbabwe's economy is agriculture based and hence its performance is mainly dependent on the extent and speed with which agriculture performs. In 2011, agriculture contributed 20.4 percent to Gross Domestic Product (GDP) (Anseeuw et al., 2012). When agriculture performs badly, overall economic growth is compromised as was the case in 2012 when GDP growth was downsized from forecasts of

9.4% to 5.6%, because of an estimated 13.2 percent decline in agricultural performance (Biti, 2012). Agriculture employs over 30 percent of the total formal work force (Kapuya et al., 2009). It is the main source of livelihoods for over 70 percent of Zimbabwe's population either directly through production or indirectly through value addition (Anseeuw et al., 2012).

Maize is the primary staple food crop for close to 98 percent of the 12.7 million people in the country (CIA, 2012). It is because of the importance of maize in the diet of many Zimbabweans that the crop is considered a national strategic crop or a food and nutrition security crop. In any given year, over a third of the budget of the Ministry of Agriculture intended for inputs is spent on procuring seed maize annually for distribution to poor and vulnerable households. The remaining sum goes towards fertilizers for the maize crop. In 2010, direct support through maize and fertilizer inputs from government was worth US$32 million. The figure increased to US$45 million in 2011/2012 although it dropped in 2012/2013 to 22 million as a result of the pressure on the economy (Jongwe, 2013).

In surplus years, maize is a source of income to 60% of the rural population (Rukuni et al., 2006). The redistribution of land under the Fast Track Land Reform (FTLR) program of 2000 changed the land holding patterns in Zimbabwe. Smallholder land holdings increased from 50 percent of total land area to 66 percent, whilst the large-scale farming land was reduced from 34 percent to 20.6 percent (MAMID, 2010). The resettlement model divided land into A1 agricultural sector-with maximum of 6 ha, A2 sector and the large-scale commercial sector (Moyo, 2011). The increase in the number of smallholder farming units increased the land planted to maize because maize has been predominantly grown by smallholder farmers since Zimbabwe's Green Revolution (Rukuni et al., 2006). After the FTLR program, over 50 percent of the 3,220,000 ha arable land has been under maize. Maize occupies over 75 percent of land under cereals (Anseeuw et al., 2012). Between 2001 and 2005, there was a 16 percent increase in the area under maize (from 1.2 million ha to 1.7 million ha). This was the period of massive land redistribution under the FTLR program. During this period, at least 3 million hectares of land was distributed to over 80,000 farming households (Moyo, 2011). The upward and downward changes from 2006-2009 in the total area planted to maize (while remaining above 1.5 million ha each year), is most likely a response to maize prices, access to and availability of agricultural inputs, among several factors.

In the 2010-2011 season, land under the maize crop increased by 20 percent to a record 2 million ha. This increase could also be explained by another wave of land redistribution. In this season, about 750,000 hectares of land which had not been previously distributed between 2001 and 2005 was redistributed to mostly A1 and A2 farmers (Moyo, 2011). The area under maize retreated to 1.69 million ha in the 2011/2012 season. This decline in land allocated to maize could be attributed, among others, to shift in

crop enterprise choice towards cash crops such as tobacco. The substitution being mostly linked to the low maize price (below production costs thus rendering the enterprise unviable); dilapidation of infrastructure; instructional problems as well as untargeted and untimely policy decisions that affected the growth of the maize subsector.

Whilst the land allocated to maize has been increasing, national yield per unit area has been declining. Average maize yield declined from a record high of 1700 ton/ha in 1996 to 1230 ton/ha in 2001. From 2001 to date, Zimbabwe has struggled to produce one ton of maize per ha. On average, Zimbabwe has been producing 0.8 ton/ha for the last 10 years. Reasons sighted include mid-season dry spells or droughts, input shortages, unstable socio-political environment, and lack of production skill (FAO/WFP, 2010, AfDB/OECD, 2003). Communal areas are characterized by low rainfall ranging from less than 450 mm to 750 mm per annum. These areas also experience midseason dry-spells and general changes in the rainfall patterns in most cases leading to poor harvest.

Methodology

Sampling and Choice Experiment

About 80% of the 1.7 million farm households of Zimbabwe live in communal areas. Communal areas are lands held under customary tenure, much of it in arid areas with poor soil, established as reserves for black Zimbabweans following the requirements of the Southern Rhodesia Order-in-Council in 1898 (Dore, 2009). These areas are characterized by chronic food insecurity and extreme poverty. Livelihoods in communal areas are based on maize systems with low external inputs and low productivity. About 60% of the land allocated to maize in the country is in communal areas and these areas produce 28% of the national maize grain stock, indicating low yields in the system.

Identification of the rural households for sampling was started by identifying the natural regions where maize is widely grown and plays an important role for food security. Zimbabwe is divided into 5 natural agro-ecological regions. Maize is the single most important crop in regions II, III, and IV. Its importance is growing in region 5 as well at the expense of small cereals such as sorghum and finger millet. Fourteen districts were purposively and proportionately selected from these regions. The purposes considered were production of maize and potential exposure to drought tolerant maize varieties. The proportion implies the relative importance (in terms of acreage and production) of maize in the natural regions. Table 1 shows the estimated natural region coverage of sample districts.

Table 1 about here!

Accordingly, we identified 11 districts that fall within natural regions II and III; two districts within natural regions III and IV, and one district within regions IV and V. Then, four villages were randomly selected from each district and hence a total of 58 villages. The household level sampling was done using random sampling method. The sampling frame was the list of all farming households in the village. Twenty five households were selected from each village for a total sample of 1400 households.

In identifying traits for the choice experiment, apart from seed price, pair wise comparison was used to identify 10 maize traits with communal farmers. Then the list was shortened to six traits with maize breeders at CIMMYT and the Zimbabwe's department of research and specialist services (DR&SS). The final set of traits included grain yield measured in ton/acre, maize cob size, grain (kernel) size, drought tolerance, grain (kernel) texture, tip (husk) cover and seed price. These traits were once again discussed with farmers and researchers for common description and level identification. Then, an efficient design was developed using SAS software by employing the macros developed by (Kuhfeld, 2010, Kuhfeld et al., 1994). The design generated 36 profiles of maize grouped in two's generating 18 choice sets. We included opt out option in each of the choice sets and blocked the choice sets into two so that each respondent would be presented with 9 choice sets of three alternatives. The traits and trait levels used in the choice experiment are indicated in Table 2 below.

Table 2 about here!

The survey was undertaken in all 14 sample districts by five enumerators and one national coordinator. Each respondent was asked to choose his/her preferred alternative maize profile in 9 choice situations. This makes the total number of completed choice situations 12,600 (i.e., 1400*9). Only in 39 (0.3%) of the choice situations, respondents preferred opting out to other alternatives.

Econometric Framework

Two common discrete choice models used in the empirical analysis of choice experiment data are conditional logit and random parameters logit. Both models are based on the random utility theory (McFadden, 1974). In this framework, utility U is assumed to be latent, with only the choice Y of alternative j by individual i in choice situation t observed. Given a choice set t with J alternatives, the utility function can generally be written as

$$U_{ijt} = \beta_i' x_{ijt} + \varepsilon_{ijt} \tag{1}$$

where x_{itj} is a vector of explanatory variables including attributes of alternatives and interactions of attributes and socioeconomic characteristics, and ε_{itj} is unexplained utility assumed to be independently and identically distributed (iid) across individuals, alternatives and choice sets with extreme value type I distribution. β_i is a conformable vector of the unknown utility weights the respondent assigns to the explanatory variables.

Conditional logit (McFadden, 1974) and mixed (random parameters) logit (Hensher and Greene, 2003, McFadden and Train, 2000) models are the two most commonly employed econometric procedures to estimate utility weights attached to the different traits. Despite their popularity, both models were found to be inadequate to estimate scale and residual taste heterogeneity in most choice contexts (Fiebig et al., 2010, Greene, 2012, Louviere et al., 2008). Conditional logit assumes that the idiosyncratic errors are iid extreme value and the tastes for observed attributes are homogeneous. The assumption about the errors gives rise to the more stringent independence of irrelevant alternatives (IIA) assumption.

The mixed logit model relaxes the IIA assumption by allowing heterogeneity of preferences for observed attributes. Hence, the utility weight (β_i) for a given attribute will be given as

$$\beta_i = \beta + \Gamma v_i \tag{2}$$

where β is the vector of mean attribute utility weights in the population, Γ is a diagonal matrix which contains σ (the standard deviation of the distribution of the individual taste parameters (β_i) around the population mean taste parameter (β)) on its diagonal, and v is the individual and choice specific unobserved random disturbances with mean 0 and standard deviation 1.

Another improvement over the conditional logit model is the scaled multinomial logit (S-MNL) model. The S-MNL formulation allows the model to accommodate scale heterogeneity; i.e., variance in utility across individuals. The added advantage of S-MNL can easily be seen for the fact that in the simple multinomial (MNL) and mixed or random parameters (MIXL) logit specifications, there is a scale or variance that has been implicitly normalized (to that of the standard extreme value distribution) to achieve identification (Fiebig et al., 2010). In S-MNL, the utility weights are given as

$$\beta_i = \beta_i \sigma_i \tag{3}$$

The scaling factor, σ_i differs across individuals, but not across choices. This also implies that the vector of utility weights β is scaled up or down proportionally across consumers by the scaling factor σ_i.

Recent developments have shown that MIXL and S-MNL can be nested to avoid the limitations observed on MIXL in particular (Louviere et al., 2008). Fiebig et al. (2010) and Greene (2012) have developed a generalized multinomial logit model (G-MNL) that nests MIXL and S-MNL. In G-MNL, the utility weights are estimated as

$$\beta_i = \beta\sigma_i + \gamma\Gamma\nu_i + (1-\gamma)\sigma_i\Gamma\nu_i \tag{4}$$

The generalized mixed logit model embodies several forms of heterogeneity in the random parameters and random scaling, as well as the distribution parameter - γ which ranges between 0 and 1. The effect of scale on the individual idiosyncratic component of taste can be separated in two parts – unscaled idiosyncratic effect ($\gamma\Gamma\nu_i$) and scaled by $(1-\gamma)\sigma_i\Gamma\nu_i$ where γ allocates the influence of the parameter heterogeneity and the scaling heterogeneity. γ also governs how the variance of residual taste heterogeneity varies with scale in a model that includes both (Fiebig et al., 2010).

Several interesting model forms are produced by different restrictions on the parameters. For example, if we set the scale parameter $\sigma_i=\sigma=1$, the model becomes ordinary MIXL. If $\gamma = 0$ and $\Gamma = 0$, we obtain the scaled MNL model. Two unique forms of G-MNL are also presented by Fiebig et al. (2010). By simply combining 2 (MIXL) and 3 (S-MNL), G-MNL-I is formed whereby the utility weight is given as:

$$\beta_i = \beta\sigma_i + \Gamma\nu_i \tag{5}$$

The other form is called G-MNL-II developed based on MIXL and explicit specification of the scale parameter to yield $\beta_i = \sigma_i(\beta + \Gamma\nu_i)$

$$\tag{6}$$

where σ_i captures the scale heterogeneity and $\sigma_i\Gamma\nu_i$ captures residual taste heterogeneity. The difference between G-MNL-I and G-MNL-II is that in G-MNL-I, the standard deviation of $\Gamma\nu_i$ is independent of the scaling of β, whereas in G-MNL-II, it is proportional to the scale heterogeneity - σ_i. G-MNL approaches G-MNL-I as γ approaches 1, and it approaches G-MNL-II as γ approaches 0. In the full G-MNL model, γ ϵ [0,1] (Fiebig et al., 2010).

In this study, the general estimation framework developed by Train (2003), Hensher and Greene (2003), Greene and Hensher (2010) and Fiebig et al. (2010) is employed. We have, however, taken into consideration some of the appealing modifications and extensions of the framework presented by Greene

(2012). Greene's specification of the utility weight explicitly shows how heterogeneities are accommodated:

$$\beta_i = \sigma_i[\beta + \Delta z_i] + [\gamma + \sigma_i(1-\gamma)]\Gamma v_i \tag{7}$$

Observed heterogeneity (explained by observed sources of variation 'z_i') is reflected in the term Δz_i while the unobserved heterogeneity is embodied in Γv_i. $\sigma_i = \exp[\bar{\sigma} + \delta' h_i + \tau w_i]$ is the individual specific standard deviation of the idiosyncratic error term, h_i denotes a set of M characteristics of individual i that may overlap with z_i, δ denotes parameters in the observed heterogeneity in the scale term, w_i is the unobserved heterogeneity (standard normally distributed), $\bar{\sigma}$ is a mean parameter in the variance, τ is the coefficient on the unobserved scale heterogeneity.

The full model (with no restriction on γ and τ) is estimated by maximum simulated likelihood (Greene, 2007). In order to impose the limits on γ, γ is re-parameterized in terms of α, where $\gamma = \exp(\alpha)/[1 + \exp(\alpha)]$ and α is unrestricted. Likewise, to ensure $\tau > 0$, the model is fit in terms of λ, where $\tau = \exp(\lambda)$ and λ is unrestricted. Combining all terms, the simulated log likelihood function for the sample of data is specified as:

$$\log L = \sum_{i=1}^{N} \log \left\{ \frac{1}{R} \sum_{r=1}^{R} \prod_{t=1}^{T_i} \prod_{j=1}^{J_{it}} P(j, X_{it}, \beta_{ir})^{d_{itj}} \right\} \tag{8}$$

where $\beta_{ir} = \sigma_{ir}[\beta + \Delta z_i] + [\gamma + \sigma_{ir}(1-\gamma)]\Gamma v_{ir}$, $\sigma_{ir} = \exp[\frac{-\tau^2}{2} + \delta' h_i + \tau w_i]$, v_{ir} and w_{ir} are the R simulated draws on v_i and w_i, $d_{itj} = 1$ if individual i makes choice j in choice set t and 0 otherwise, and $P(j, X_{it}, \beta_{ir}) = \frac{\exp(x'_{itj}\beta_{ir})}{\sum_{j=1}^{J_{it}} \exp(x'_{itj}\beta_{ir})}$.

Estimating willingness to pay for maize traits and trait levels

This generalized mixed model also provides a straightforward method of re-parameterizing the model to estimate the taste parameters in willingness to pay (WTP) space, which has recently become a behaviorally appealing alternative way of directly obtaining an estimate of WTP (Fiebig et al., 2010, Fosgerau, 2007, Greene, 2012, Scarpa et al., 2008, Train and Weeks, 2005, Hensher and Greene, 2011). If $\gamma = 0$, $\Delta = 0$ and the element of β corresponding to the price or cost variable is normalized to 1.0 while a nonzero constant is moved outside the brackets, the following re-parameterized model emerges:

$$\beta_i = \sigma_i\beta_c\left[\left(\frac{1}{\beta_c}\right)(\beta + \Gamma v_i)\right] = \sigma_i\beta_c\left[\frac{1}{\theta_c + \Gamma v_i}\right] \tag{9}$$

This model produces generally much more reasonable estimates of willingness to pay for individuals in the sample than the model in the original form in which WTP is computed using ratios of parameters (Greene and Hensher, 2010, Train and Weeks, 2005, Hensher and Greene, 2011).

Four formulations were used in estimating the choice models and the derivatives (the heterogeneity in mean and the willingness to pay models). The first specification was without any control on the key parameters γ and τ resulting in the general mixed logit model. The second specification fixed γ at zero resulting in the type II generalized multinomial logit model (G-MNL-II) of (Fiebig et al., 2010) also known as scaled random parameters logit model (Greene, 2012). The third specification fixed γ at 1 generating the type I generalized multinomial logit (G-MNL-I) (Fiebig et al., 2010) or the hybrid model (Greene, 2012). The fourth specification fixed τ at one. The model quality indicators did not show any considerable difference across the four models for all estimations. Therefore, the results of the four choice models will be presented and only the unrestricted model result will be presented for willingness to pay and heterogeneity in mean estimations.

Results and Discussion

The sample population

Most (77.4%) of the sample households were male headed and the average age of the heads of the sample households was computed to be only 38 years while ranging from 12 to 94 years. Literacy level in schooling years of the household heads was on average 9 years. Literacy ranged from none to 18 years of education. The sample households had an average size of about 6 persons with the number of female members slightly higher than that of male members. The mainstay of livelihood for the sample households is crop and livestock farming. Three out of four respondents depended on farming whereas about 12% indicated petty trading or other own business to be their mainstay. Temporary and permanent employment was also reported by 10.7% of the respondents as primary source of livelihood. The average farm land holding was found to be 7 acres; i.e., 2.83 hectares. On average the sample households allocated 60% of their land to maize highlighting the importance of maize in their livelihoods (Table 3).

Respondents were asked to identify the maize varieties they grew in 2012/13 season and what they were growing in the current 2013/14 season. We are presenting the 10 most common varieties that account for about 88% of the households coincidentally in both seasons. Varieties of Seed Co – one of the oldest seed companies in Zimbabwe and in fact in southern Africa – were found to be quite dominant. SC513 is the most commonly (34.1% in 2012/13 season and 31% in 2012/13 season) grown variety in both seasons and the most preferred maize variety in Zimbabwe (Chikobvu et al., 2010). Seed Co varieties of 500 series, 400 series, SC03, and SC401 were also found to be quite common in both seasons. PANNAR varieties – referred to as such by farmers - and those specifically mentioned; i.e., PAN413 and PAN53 are also among the top ten varieties under production in both seasons (Table 4).

Econometric results

In all models, τ was found to be insignificant implying that there is no any considerable degree of scale heterogeneity in the data. In fact, the choice experiment on maize traits can hardly be considered as a difficult choice situation for farmers and scale heterogeneity is less important in such simple choice contexts (Fiebig et al., 2010). Similarly, γ was found to be very close to zero implying that the variance of residual taste heterogeneity increases with scale justifying the estimation of G-MNL in general and G-MNL II model in particular[1].

Basic G-MNL model results

Results of the full G-MNL model (with no restriction on τ and γ) show that drought tolerance, yield, grain size, cob tip (husk) cover, semi-flint texture, and big cob size are the traits that have a strong, in order, and positive effect on choice of a maize variety. Flint texture (compared to dent) and medium cob size (compared to small size) were found to be significantly and negatively related to the likelihood of choosing a given maize variety. Unobserved heterogeneities were also evident around mean taste parameters for yield, grain size, drought tolerance, tip cover and price (Table 5).

The model with gamma fixed at zero (G-MNL-II/S-RPL: $\gamma=0$) generated comparable results to that of the unrestricted model (full G-MNL). The only difference is that medium cob size (compared to small size)

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[1] Summary of model performance indicators for all estimated models is available from the corresponding author upon request.

was found to be not significantly affecting the likelihood of choosing a given maize variety. This model showed more pronounced unobserved heterogeneities compared to full G-MNL. In addition to those observed in full G-MNL, unobserved heterogeneities were found to be significant around the mean taste parameters for medium cob size and the two levels of texture (semi-flint and flint).

The model with $\gamma = 1$ (G-MNL-I/Hybrid model) also generated essentially the same result as full G-MNL with heavier coefficients for the mean taste parameters and lighter coefficients for the unobserved heterogeneity coefficients (standard deviations of the random taste coefficients). The fourth model with the restriction $\tau = 1$ (G-MNL (τ=1)) resulted in slightly different coefficients both for mean taste parameters and standard deviations of random taste parameters compared to the other three models. Coefficients are much heavier than in the other models and the flint texture level was also positive and statistically insignificant in this formulation. Unobserved heterogeneity was also evident across taste parameters of all traits except price.

Importance of drought tolerance was revealed in all formulations even compared to the ultimate measure of performance of a variety; i.e., yield (Table 5). The temporal dimension of traits being considered is crucially important in understanding the relative importance of the traits from farmers' point of view. Farmers are aware that the ultimate yardstick to measure how good a variety is can only be through the yield per unit area. Yet, farmers need to be certain that a given variety has the necessary attributes to yield as much as possible in their heterogeneous and risk prone environments. The fact that a variety has drought tolerance trait can therefore be more convincing to the farmers in selecting a variety than mere exposition of the potential yield of the variety in question.

Other traits are also important in maize variety choice decisions. For instance, cob tip cover (or husk cover) is an important attribute in rural Zimbabwe given the challenges imposed by birds and other rodents. Similarly, the texture of the grain has an important implication in terms of expected grain yield per unit area, poundability, and flour yield per unit of grain. Farmers are aware that dent textured maize is softer and can easily be pounded compared to flint maize and flint maize gives higher flour per unit of grain. It is also known among farmers that the yield per unit area is normally higher for dent and semi-flint maize compared to flint maize, other things held constant. This is quite different from the preferences for flint textured maize in Malawi as farmers consider dent textured maize to be of low storability.

Table 5about here!

Heterogeneity in maize trait preferences

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Unobserved heterogeneity around the mean of the taste parameters was quite consistently evident with respect to yield, drought tolerance, grain texture (flint and semi-flint), and husk cover. Therefore, we introduced some observed sources of variation to identify which factors are responsible for the heterogeneity. The heterogeneity in mean variables were selected after an iterative process of model estimation and comparison based on intuition and the conventional criteria of log likelihood, Akaike Information Criterion (AIC) and Bayesian Information Criterion (BIC) (Kadane and Lazar, 2004). The heterogeneity models estimated generated highly comparable results (Table 6) and hence only the unrestricted model (full G-MNL) will be discussed.

Gender and age of the household head, household size, and occupation of the household head were found to be the factors that explain the variation around the average level of taste preference for the traits. Male farmers were found to be more interested in grain yield than female farmers that took part in the choice experiment. Most rural households in Zimbabwe are male headed and males take the lead role in managing and conducting the on-farm production part of the maize economy. In choosing varieties, male farmers would therefore be expected to focus more than their female counterparts on grain yield trait.

Household size was also found to be influencing the interest in grain yield positively and significantly. This is intuitive that bigger households would certainly be keener than smaller households to have varieties that are high yielding, everything else constant. Given the semi-subsistence nature of the communal households in Zimbabwe that the most important priority is producing sufficient food for the family, the interest in yield trait cannot be overemphasized.

Farmers engaged in temporary employment also showed strong interest in grain yield trait compared to those fully engaged in farming. The respondents are farmers who are trying to complement their livelihoods with temporary employment. Limited resources and/or low productivity of their major activity might be the reason why they are engaging in temporary employment. It is therefore expected that they would show strong interest in grain yield trait of the maize varieties they choose to grow.

Only 1.1% of the respondents are engaged in activities not related to farming, paid permanent and temporary employments, and trading. These respondents were categorized as households that depend on other sources of income. These households were found to have significantly less interest in grain yield trait compared to those who depend on farming for a living.

Women respondents were found to be more interested than men in drought tolerance trait. This is not unexpected given the role of women in seed marketing and variety selection in rural Zimbabwe. Variety

selection and seed marketing in Zimbabwe is done after a long and inclusive intra-household consultation. Women are very keen in making sure that the varieties being grown are drought tolerant as they sense the risks the household faces in terms of food shortage more closely than the men respondents. Therefore, this may suggest higher relative risk aversion among women compared to men.

Interest in drought tolerance was found to be positively related to household size as well. In communal areas household size increment directly puts pressure on the family food demand and hence big households would be expected to be more interested in varieties that can yield under the formidable risks of drought. It is also important to note that maize is the highest priority crop and drought is the most important challenge for its production in communal areas of Zimbabwe (Chikobvu et al., 2010).

Households headed by those engaged in petty trading are less interested in drought tolerance trait in maize compared to those headed by farmers. Petty traders are less likely to be fully or even partially engaged in crop farming and hence less concerned about drought tolerance trait of maize. Their interest is expected to be in traits with direct implications on the marketability of the maize.

Households headed by those engaged in temporary employments are very interested in drought tolerance in maize. As discussed above in relation to grain yield, these are people who do temporary employment mainly to supplement their livelihoods. These people would be expected to be very risk averse and keen in technologies that reduce the risk they could possibly face. Drought being an important part of the farming system, it is therefore expected to see respondents with temporary employment to show high interest in drought tolerance.

On the contrary, households headed by those engaged in other activities are less interested in drought tolerance trait in maize compared to farmers. This is not unexpected as this group of respondents are rarely engaged in farming and hence, like petty traders, possibly not interested in the challenges maize production is facing. Their interest could be in the consumption related attributes of maize as can be concluded from the heterogeneity in mean coefficients for the different production related traits.

Another trait with significant heterogeneity in preferences among respondents is semi-flint texture. The texture has direct relationship with the yield, flour content and poundability of the maize grain. Male respondents are more interested in semi-flint texture (compared to dent texture) than the females. Household size is also positively related to high interest in semi-flint maize. This could be related to the higher quantity of flour expected from semi-flint maize compared to dent maize.

Respondents that are engaged in petty trading are more interested in semi-flint than dent texture in maize. This is an important trait for petty traders especially in terms of marketability as the demand for maize with this texture is high due to its combined features of softness for pounding and higher grain yield per unit area (as dent maize) and high flour per unit of grain (as flint maize).

Table 6 about here!

Willingness to pay for maize traits

Based on full G-MNL formulation, the willingness to pay (WTP) estimation done in WTP space resulted in coefficients in the realistic range given the price of maize seed in the market. The WTP values show that the implicit price of drought tolerance (DT) is way higher than all other traits. WTP for DT is followed by that of grain yield and grain size, in order (Table 7). The WTP for an increase or change in an attribute level is the price increase, which, combined with the attribute increase, leaves the deterministic part of the respondent's utility for a profile unchanged and hence the choice probability unchanged (Fiebig et al., 2010).

The absolute figures of the WTP are hardly useful due to the unavoidable changes in prices. Therefore, more emphasis is on the relative WTP weights of the traits. Sample farmers are willing to pay a premium for drought tolerance that is 1.75 times the amount they are willing to pay for an increase in grain yield of one ton/acre. The value farmers attach for a drought tolerant maize variety over a non-tolerant one is 8.3 times the value they attach for a change from small to big cob size. Similarly, farmers value drought tolerance 2.7 higher than the value they attach to changing a maize variety from small grain sized to large grain sized. In a similar fashion, the WTP for drought tolerance in maize is 14.7 times higher than the WTP for semi-flint texture over dent texture of maize. The value farmers attach for drought tolerance is 3.1 times higher than the implicit price they attach to changing a variety from open tip cover to covered one.

Table 7 about here!

Conclusion

Drought and the risk associated with it will continue to be formidable challenges for rainfed maize production in the water-scarce communal areas of Zimbabwe. This is quite inevitable as climate change is likely to lead to increased temperature by an average of 2.1 °C in SSA and water scarcity, particularly in Southern Africa, in the coming decades (Hendrix and Glaser, 2007, Lobell et al., 2008). Studies have

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indicated that an increase in temperature of 2°C would result in a greater reduction in maize yields within SSA than a decrease in precipitation by 20% (Lobell and Burke, 2010).

Against this background, virtually no argument can be valid against the development and deployment of crop technologies that reduce the vulnerability of farming communities to dry spells and prolonged droughts. In maize based livelihood systems, along with water conservation and soil management, drought tolerant maize is a key option available for farmers against drought.

Given the appropriateness of the technology, it is imperative to have considerable adoption of the DT maize varieties to bring about any impact at farm household level. Farmers' adoption decisions for improved maize varieties are essentially governed by their willingness to pay for the different traits. It was therefore important to elicit the preferences of farmers of the traits of maize and estimate the implicit price they are willing to pay for the traits.

We employed choice experiment approach to elicit preferences for traits of maize and used recent developments in discrete choice modeling to quantify the implicit prices farmers are willing to pay for the traits – particularly drought tolerance. All eight formulations of basic G-MNL and G-MNL-with-mean-heterogeneity models consistently showed that drought tolerance is the most important trait in choosing a maize variety in communal areas. The different formulations used in this paper have also shown that scale heterogeneity is not that important as a source of taste heterogeneity among rural maize growers/consumers in Zimbabwe. This implies that whatever heterogeneity is there is mainly due to taste heterogeneity as a result of both observable and unobservable factors. The study has identified sources of observed and unobserved heterogeneities in a rather concise way.

The uncertainty that DT maize might not be appealing to poor farmers as much as some technologies, such as Bt cotton (Lybbert and Bell, 2010), could only be cleared only if the promotion of DT materials is done in the right manner and to the right target community. This study has shown that in communal areas of rural Zimbabwe, drought tolerance is the most important trait of maize varieties they want to grow. Women farmers, households with large families, and households headed by people who supplement their livelihoods with temporary employment were found to be more interested in the DT trait. The promotional activities need to design tailor made and focused marketing of the added values of these specialized varieties in order to target the more enthusiastic sectors of the community for faster dissemination of the technology.

Innovative ways of promoting DT maize vis-à-vis creating awareness in contextual understanding of drought and drought risk shall be employed to enhance adoption of new DT maize varieties by risk prone farming communities. Given the high level of rural literacy and the high rate of adoption of improved maize, trait based promotion and marketing of varieties would be the right strategy. Yield and other traits, as important as they are, should be emphasized only when they need to be and not at the expense of the other traits preferred by farmers in their respective contexts.

Table 1: Estimated natural region coverage of sample districts

District	% NR I	% NR II	% NR III	% NR IV	% NR V
Chivi	-	-	60	40	-
Masvingo	-	20	75	5	-
Zaka	-	90	10	-	-
Makoni	-	60	40	-	-
Mount Darwin	-	50	50	-	-
Guruve	-	50	50	-	-
Gokwe North	-	60	40	-	-
Kadoma	-	30	70	-	-
Mutoko	-	5	95	-	-
Murehwa	-	95	5	-	-
Makonde	-	90	10	-	-
Shamva	-	70	30	-	-
Gwanda	-	-		40	60
Umzingwane	-	-	30	70	-

Table 2: Maize traits and trait levels used in the choice experiment

Variable	Description	Levels	Reference level
Yield	Grain yield measured in ton/acre, ranging from 0.5 to 3.5 ton/acre in communal areas.	0.5, 1.5, 2.5, 3.5	
Cob size	Observation based on the relative maize cob size (based on length and diameter).	Small, Medium, Big	Small
Grain size	Observation based on the relative kernel size.	Small, Large	Small
Drought tolerance	The ability of a maize variety to yield more than other maize varieties under water deficit stress while yielding similarly or better under well-watered conditions.	Not tolerant, tolerant	Not tolerant
Grain texture	Hard, semi-hard or soft seed coat.	Dent, semi-flint, flint	Dent
Tip (husk) cover	Describes the extent to which the end of the maize cob is covered with sheath leaves.	Not covered, covered	Not covered
Seed price	Maize seed price in USD/kg. Seed price ranges from 1.5 to 3.5 USD/kg – including both open pollinated and hybrid maize.	1.5, 2.5, 3.0, 3.5	

Table 3: Description of the sample households

	Mean/Freq(%)	Min.	Max	St.dev.
Gender of HH head				
Male	22.6			
Female	77.4			
Age of household head (in years)	37.95	12.00	94.00	15.81
Literacy of household head (in years)	8.83	.00	18.00	3.29
Total household size	5.72	1	36	2.72
Total number of females in the household	2.92	0	21	1.72
Total number of males in the household	2.80	0	18	1.67
Mainstay of HH livelihood				
Farming	75.7			
Petty trading or other own business	12.4			
Temporary or permanent employment	10.7			
other sources of income	1.1			
Total farm land owned (acre)	6.97	.50	185.00	8.53
Land allocated to maize (% total land owned)	59.98	2.00	100.00	22.77

Table 4: The ten most frequently grown maize varieties

	2012/2013 season		2013/14 season	
Rank	Variety	Growing HHs (%)	Variety	Growing HHs (%)
1	SC513	34.1	SC513	30.9
2	PANNAR	16.2	PANNAR	16.1
3	SC500 series	14.4	SC500 series	12.9
4	SC400 series	6.9	SC400 series	8.1
5	PIONEER	5.9	PIONEER	7.3
6	PAN413	4.1	PAN413	4.3
7	SC403	1.7	SC6 series	2.4
8	PAN53	1.6	SC403	2.1
9	Retained	1.5	PAN53	2.1
10	SC401	1.4	SC401	1.8
Total		87.8		88

Table 5: G-MNL model results of variety choice model

	Full G-MNL		G-MNL-II (γ=0)		G-MNL-I (γ=1)		G-MNL (τ=1)	
	β	St.err.	β	St.err.	β	St.err.	β	St.err.
Taste parameters								
Yield	1.45‡	0.06	1.33‡	0.053	1.59‡	0.070	2.21‡	0.116
Medium size cob	-0.08†	0.03	-0.04	0.034	-0.23‡	0.041	-0.44‡	0.063
Large size cob	0.20‡	0.03	0.16‡	0.03	0.32‡	0.036	0.50‡	0.056
Grain size	0.55‡	0.07	0.72‡	0.056	0.88‡	0.091	2.55‡	0.203
Drought tolerant	2.02‡	0.09	2.01‡	0.063	2.72‡	0.116	5.08‡	0.224
Semi-flint texture	0.27‡	0.04	0.36‡	0.03	0.25‡	0.039	0.16†	0.079
Flint texture	-0.16‡	0.05	-0.3‡	0.041	-0.17‡	0.051	0.14	0.112
Covered tip	0.43‡	0.07	0.56‡	0.066	0.78‡	0.094	2.42‡	0.206
Seed price	-0.26‡	0.02	-0.26‡	0.019	-0.23‡	0.025	-0.36‡	0.030
Heterogeneity in mean								
Yield	0.82‡	0.09	0.74‡	0.081	0.9‡	0.085	1.14‡	0.249
Medium size cob	0.04	0.14	0.16‡	0.052	0.11	0.080	0.17*	0.090
Large size cob	0.10	0.07	0.05	0.069	0.04	0.076	0.24‡	0.067
Grain size	0.50‡	0.09	0.26†	0.121	0.66‡	0.070	0.55‡	0.130
Drought tolerant	0.51‡	0.07	0.67‡	0.079	0.06	0.097	1.65‡	0.210
Semi-flint texture	0.02	0.09	0.13*	0.066	0.08	0.071	0.22‡	0.077
Flint texture	0.12	0.08	0.18†	0.074	0.25‡	0.063	0.30†	0.137
Covered tip	0.47‡	0.10	0.61‡	0.082	0.43‡	0.082	0.41*	0.213
Seed price	0.11†	0.05	0.24‡	0.034	0.26‡	0.025	0.14	0.141
Tau	0.38	1.392	0.31	1.242	0.49	1.640	1.14	3.414
Gamma	0.04	0.128	0	fixed	0.09	3.020	0.26	0.770
Sigma(i)	0.06	102.96	0.15	1.44	0.65	1.480	0.39	3.576

Note: ‡, †, * imply significance at 1%, 5%, 10% level, respectively.

Table 6: Heterogenteity in mean taste parameters models

	Full G-MNL		G-MNL-II (γ=0)		G-MNL-I (γ=1)		G-MNL (τ=1)	
	β	St.err.	B	St.err.	β	St.err.	β	St.err.
Taste parameters								
Yield	0.46‡	0.132	0.46‡	0.136	0.42‡	0.137	1.37‡	0.254
Medium size cob	-0.17‡	0.031	-0.17‡	0.033	-0.19‡	0.033	-0.57‡	0.052
Big size cob	0.19‡	0.070	0.19‡	0.067	0.22‡	0.067	0.45‡	0.084
Grain size	0.57‡	0.054	0.56‡	0.051	0.54‡	0.053	1.81‡	0.133
Drought tolerant	2.21‡	0.149	2.19‡	0.170	2.16‡	0.172	4.85‡	0.315
Semi-flint texture	0.01	0.080	0.02	0.071	-0.04	0.072	0.19*	0.110
Flint texture	-0.14‡	0.042	-0.13‡	0.040	-0.15‡	0.040	0.07	0.060
Covered tip	0.57‡	0.063	0.57‡	0.064	0.50‡	0.063	1.90‡	0.142
Seed price	-0.46‡	0.023	-0.46‡	0.021	-0.39‡	0.018	-0.36‡	0.029
Observed heterogeneity								
Yield*Gender	0.29‡	0.080	0.29‡	0.083	0.33‡	0.084	0.28†	0.135
Yield*HH size	0.03‡	0.014	0.03†	0.015	0.05‡	0.015	-0.02	0.027
Yield*Petty trader	0.06	0.122	0.06	0.117	0.12	0.114	-0.18	0.229
Yield*Temporary	0.54‡	0.130	0.52‡	0.134	0.66‡	0.135	0.23	0.247
Yield*Other jobs	-0.85‡	0.256	-0.84‡	0.233	-1.06‡	0.224	-0.38	0.523
Big cob*Gender	0.06	0.040	0.06*	0.038	0.08†	0.039	-0.06	0.052
Big cob*HH size	0.00	0.008	0.00	0.007	0.00	0.007	0.02	0.009
Big cob*Petty trader	-0.04	0.064	-0.04	0.058	-0.03	0.058	0.13*	0.078
Big cob*Temporary	0.02	0.066	0.02	0.060	0.04	0.061	0.03	0.079
Big cob*Other jobs	0.00	0.136	0.00	0.116	-0.01	0.118	-0.24*	0.135
DT*Gender	-0.87‡	0.075	-0.85‡	0.090	-1.01‡	0.099	-0.46‡	0.131
DT*HH size	0.02†	0.011	0.02	0.014	0.02	0.015	-0.03	0.019
DT*Petty trader	-0.16*	0.091	-0.16	0.117	-0.11	0.120	0.06	0.170
DT*Temporary	0.90‡	0.102	0.89‡	0.136	0.92‡	0.142	0.77‡	0.194
DT*Other jobs	-0.75‡	0.177	-0.75‡	0.243	-0.91‡	0.250	-1.07‡	0.301
DT*Literacy	0.00	0.010	0.00	0.012	0.00	0.012	-0.09‡	0.019
Semi flint*Gender	0.09†	0.042	0.09†	0.040	0.09†	0.040	0.11†	0.052
Semi flint*HH size	0.02‡	0.008	0.02‡	0.008	0.03‡	0.008	-0.01	0.010
Semi flint*Petty trader	0.22‡	0.073	0.22‡	0.062	0.21‡	0.062	0.17*	0.100
Semi flint*Temporary	0.01	0.075	0.01	0.064	-0.01	0.064	0.05	0.103
Semi flint*Other jobs	-0.24	0.164	-0.23*	0.124	-0.22*	0.125	-0.16	0.220
Heterogeneity in mean								
Yield	0.59‡	0.078	0.59‡	0.084	0.50‡	0.101	0.86‡	0.123
Medium size cob	0.02	0.148	0.02	0.075	0.01	0.075	0.09	0.101
Big size cob	0.06	0.089	0.06	0.058	0.11†	0.057	0.12*	0.070
Grain size	0.40‡	0.091	0.37‡	0.096	0.37‡	0.088	0.22	0.156
Drought tolerant	0.65‡	0.055	0.66‡	0.094	0.67‡	0.089	1.12‡	0.104
Semi-flint texture	0.06	0.089	0.05	0.079	0.09	0.078	0.05	0.068
Flint texture	0.18†	0.071	0.19†	0.086	0.18†	0.080	0.17†	0.081

Covered tip	0.50‡	0.087	0.50‡	0.102	0.27	0.246	0.04	0.126
Seed price	0.19‡	0.036	0.21‡	0.038	0.10†	0.044	0.11‡	0.042
Key model parameters								
Tau		0.14	0.723	0.14	0.739	0.13	0.889	0.86	3.010
Gamma		0.06	0.319	0.00	Fixed	0.50	3.355	0.11	0.401
Sigma(i)		0.05	22.120	0.02	0.76177	0.27	0.544	0.22	2.761

Note: ‡, †, * imply significance at 1%, 5%, 10% level, respectively.

Table 7: Willingness to pay for maize traits in willingness to pay space

	WTP (full G-MNL model)	
	Coefficient♣	St.error
Taste parameters		
Yield	-4.29‡	0.272
Medium size cob	0.62‡	0.096
Large size cob	-0.90‡	0.089
Grain size	-2.79‡	0.206
Drought tolerant	-7.49‡	0.354
Semi-flint texture	-0.51‡	0.102
Flint texture	0.25	0.124
Covered tip	-2.43‡	0.213
Seed price	1.00	fixed parameter
Distns. of RPs. Std.Devs or limits of triangular		
Yield	3.45‡	0.260
Medium size cob	0.72‡	0.142
Large size cob	0.34‡	0.128
Grain size	2.07‡	0.198
Drought tolerant	3.90‡	0.266
Semi-flint texture	0.54‡	0.111
Flint texture	0.08	0.171
Covered tip	0.65‡	0.247
Seed price	0.00	fixed parameter
Tau	2.71	2.255
Gamma	0.00	fixed parameter
βWTP	-0.39‡	0.082
S. βWTP	0.09	0.076
Sigma (i)	0.73‡	0.146

Note: ‡, †, * imply significance at 1%, 5%, 10% level, respectively. ♣ Signs of coefficients need to be reversed as the coefficient of price was fixed to be 1.

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