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Full Research Article

Not my cup of coffee: Farmers' preferences for coffee variety traits – Lessons for crop breeding in the age of climate change[1]

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Abstract. The advent of biotechnology and conservation of genetic resources hold promise to improve traits to meet the challenges to coffee growing from climate change. Developing new varieties by integrating traits in high demand by farmers could greatly increase farmers' adoption of new varieties. This study aims to inform breeding priority setting by examining farmers' preferences for coffee traits. A Discrete Choice Experiment was applied to smallholder farmers in northern Ethiopia to map their willingness-to-pay for improvements in four coffee traits: i) yield, ii) weather tolerance, iii) disease resistance, and iv) the maturity period. The traits are important to the farmers in their choice of coffee varieties. They prefer weather tolerant and disease resistant varieties; implying that they prefer yield stability over high yielding and early maturing varieties. Education level, access to irrigation and farmers' experience in coffee farming explain the preference heterogeneity across farmers. These results suggest that breeding programs should give priority to yield stability in order to increase farmers' adoption of new varieties, and secure *in situ* preservation of these traits. Thus, *ex situ* conservation programs are needed for early maturing and high yielding varieties, which farmers do not give priority to maintain in their own fields. This would improve climate resilience of coffee farming, and at the same time conserve the Arabica coffee genetic heritage of Ethiopia.

Keywords. Coffee, traits, crop breeding, climate change, discrete choice experiment, willingness-to-pay.

JEL Codes. Q18, Q51, Q55, Q57.

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1. Introduction

Coffee is grown by 20-25 million families in more than 80 tropical and subtropical countries (Bacon, 2005; Vega et al., 2003). Two main coffee species are grown; Arabica coffee (*coffea arabica)* and Robusta coffee (*coffea canephora*), with the former accounting for more than half of the world coffee production. Meeting the growing demand for coffee while safeguarding the genetic biodiversity of coffee is, however, a great challenge for policy makers. The advent of biotechnology and conservation of genetic resources hold promise to improve phenotypes of high economic importance and bring socially desirable outcomes.

Ethiopia is one of the world's largest coffee producing countries and known to harbor a wide range of coffee genetic diversity in a diverse array of coffee farming systems. There are more than 5,000 varieties of Arabica coffee in the country (Labouisse et al., 2008, Tsegaye et al., 2014), and they can still be found growing wild or semi-wild in the undergrowth of tropical highland forests. Ethiopian foreign exchange earnings largely depend on coffee export. There are four main coffee farming practices in Ethiopia: i) forest coffee, accounting for 8-10 % of the production, ii) semi-forest coffee (30-35 %), iii) garden coffee (50-57 %) and iv) plantations (5 %)(Kufa, 2012). Thus, 95 % of the total coffee produced can be attributed to smallholder farmers.

The productivity of forest coffee and semi-forest coffee farming is about 200-500 Kg per hectare, which is lower than the national average productivity (600 -700 Kg per hectare). The coffee species in the forests and farms vary in productivity per hectare, appearance and internal genetic structure (López-Gartner et al., 2009). The vast genetic variability in *Coffea arabica* genotypes of Ethiopia provides opportunities for creating coffee varieties, through selection and hybridization, with good yield performance, distinct quality characters, and resistance to major diseases.

The few common pests and coffee diseases include coffee berry disease (CBD) *(Colletotrichum kahawae*), coffee root-knot nematode (*Meloidogyne spp*.) and coffee rust (Muller et al., 2009; Dubale & Teketay, 2000). The threat of CBD remains prevalent in coffee growing regions despite research efforts and policy interventions encouraging planting of disease resistant coffee varieties and fungicide spraying. Pest and disease resistant cultivars yield economic benefits because they reduce yield losses and pesticide costs of coffee growers (Hein & Gatzweiler, 2006).

Previous studies and policies on annual crops narrowly focus on evaluating the benefits of high yielding varieties, but farmers' adoption of these improved varieties is low (e.g., Dalton, 2004; Shiferaw et al., 2014; Zeng et al., 2014). In addition, evidence from multi-attribute crop studies in developing countries show that farmers exhibit higher preferences for drought tolerant than high yielding crops (Asrat et al., 2010; Kassie et al., 2017). However, these studies examine farmers' preferences for crops such as teff (*Eragrostis abyssinica*) and maize. In contrast, coffee is arguably more robust to weather shocks than annual crops, but the practice of coffee farming is more challenging because of long-lasting effects of farming decision, less opportunities for inter-annual agronomic adjustments, as well as the ecological importance of preserving genetic diversity.

Farmers focus on their private economic benefits, and select and cultivate coffee varieties based on the benefits they obtain and/or expect to obtain from a particular trait

(Hein & Gatzweiler, 2006). However, farmers' emphasis on adoption of high yield coffee varieties could erode the genetic diversity of coffee in the forests and the semi-forest coffee farms. Fluctuating market price of coffee, coffee diseases, increased frequency of extreme weather events, and substitute cash crops like khat *(Catha edulis)* can also reduce the genetic diversity of coffee.

In coping with the environmental stressors, farmers' selection of coffee varieties to cultivate and maintain on their farm along with natural processes over generations of cultivation shapes the genetic structure of coffee (Baidu-Forson et al., 1997; Smale et al., 2001). Farmers' interest in increasing yield per hectare, reducing yield loss or shortening the waiting period to start harvesting a normal yield might motivate their decisions to cultivate new varieties and maintain them in their fields.

Climate change is threatening global coffee yields as changing temperatures and rainfall patterns affect plant growth. The changing climate may also be leaving coffee plants more vulnerable to diseases. Thus, in the age of climate change it is important to conserve the genetic diversity in Arabica coffee in countries like Ethiopia, as this genetic pool is likely to improve the possibilities for adapting coffee growing to future climates and secure the livelihood of smallholder coffee farmers in developing countries (FAO 2015)..

This paper aims at increasing our understanding of Ethiopian smallholder farmers' preferences for Arabica coffee traits. This knowledge can be used to construct breeding programs for coffee varieties farmers are likely to adopt, and thus conserve *in-situ*. For example, if farmers have strong preferences for high yield traits, they are more likely to maintain such varieties in their farmed fields. However, the farmers would then be less likely to cultivate or maintain other coffee varieties with lower yields, but with drought tolerance and other traits that could critically affect the future ability of coffee to adapt to climate change. In order to preserve these traits, *ex-situ* conservation efforts would be needed to supplement on the farm (*in situ*) conservation.

While previous studies of Ethiopian smallholder farmers have examined trait preferences for annual crops like teff and sorghum (Asrat et al., 2010), and found environmental adaptability and yield stability to be important, very little is known about the trait preferences of farmers for perennials like coffee.

This paper seeks to answer the following three research questions: 1) Which traits of Arabica coffee varieties do smallholder farmers prefer to cultivate? 2) Are there trait preference variations among the farmers? 3) Which sociodemographic factors explain the variations in farmers' preferences for coffee traits?

We employ a discrete choice experiment (DCE) to elicit farmers′ preferences and willingness-to-pay (WTP) for improvements in the following traits of Arabica coffee: i) yield per hectare, ii) weather tolerance, iii) diseases resistance, and iv) the maturity period. We also explore the preference heterogeneity among the smallholder farmers, and the sources of heterogeneity. The latter is found to be important for designing targeted communication programs, differentiated product offerings, and for identifying market segments and market niches (Allenby & Rossi, 1999). Thus, the results from this study can be used in the dissemination and adoption of improved coffee varieties.

2. Method and Data

2.1 Description of the Study Area

The study area is the Raya Alamata and Raya Azebo districts of the regional state of Tigray in northern Ethiopia. The study area is located about 600 km north of Addis Ababa, the capital of Ethiopia and 180 km south of Mekelle, the capital of the regional state of Tigray with about 4 million inhabitants. Most people in this rural area base their livelihood on rain-fed agriculture. The study area includes most of the Raya valley, which is one of the focal areas for agricultural expansion with its fertile soils and high agricultural potential. The Ethiopian Ministry of Water Resources initiated a hydrogeological study in the Raya valley in 2008 aiming to encourage farmers to adopt new technologies to improve productivity and ensure food security in the region (Ayenew et al., 2013). The study area, like the other regions in Ethiopia, has seen frequent variability in the weather; i.e. fewer normal years and more frequent droughts and flooding (Siam & Eltahir, 2017). Higher rainfall variability in the region has become a challenge for agriculture and environmental conservation as farmers have not adopted technologies that could mitigate crop yield losses.

Agriculture, being the main source of livelihood activity, involves a mixture of food and cash crop production. The main crops grown are maize, sorghum and teff; but also coffee and khat are found. Fruits are also grown as cash crops in the lowland areas. Although annual rainfall is moderate, ranging from 450 to 600 mm, the availability of farmland and fertile clay loam soils makes the area well suited to crop production. Since 2001/02, the regional government has made unsuccessfully efforts to get khat producers to convert to coffee production. The regional government has banned transportation, selling and buying of khat in the regional markets during the coronavirus pandemic state of emergency, and is planning to introduce new lasting laws to permanently prohibit the use and marketing of khat. One of the tentative measures proposed is to provide subsidies and other incentives to farmers that convert from khat to coffee farming. Thus. understanding farmers' preferences for coffee traits, and factors explaining potential preference heterogeneity among these farmers, could help us understand how effective alternative measures would be and improve their design.

2.2 Design of survey, choice experiment and attributes

2.2.1 Survey instrument

Discrete Choice Experiments (DCEs) enable us to study goods and attributes for which no market exists (Hanley et al 2001). We use DCE to evaluate farmers' preferences for the various traits of coffee varieties, as the other Stated Preference technique of Contingent Valuation is not able to value each individual trait. The DCE approach is based on a combination of Lancaster's household production theory (Lancaster, 1966), and McFadden's random utility theory (McFadden, 1973). Lancaster's household production theory states that the total utility of a good is derived from the characteristics or attributes of the good (Lancaster, 1966); while the random utility maximization (RUM) model is used for analyzing discrete choices, based on the assumption of utility maximizing behavior of individuals (McFadden, 1973). In DCEs, individuals are asked to make repeated hypothetical choices among alternatives in choice sets where the pre-specified levels of the different attributes vary.

The final survey instrument was designed in a stepwise process; including discussions with key informants and experts from Mekelle University, focus group discussions with the farmers; and a series of pretests of the survey instrument prior to the final survey; see table 1. We conducted pre-test surveys in April and May 2016 in four villages in the study area. In the first exploratory survey, we used a structured questionnaire, and carried out face-to-face interviews with informed village community members and local agriculture and development extension agents in the study area. The focus group discussants (N= 20, in five groups, each with four participants) and informant interviewees were used to determine the coffee attributes that were most important to them and to the community. In a pre-test survey we tested the questionnaire on a broad range of respondents in order to reflect the variation we expected to see in the final survey sample and checked whether respondents understood the questionnaire. We kept refining and clarifying the attributes and their levels using reports and opinions from discussants to make them easier for the respondents to understand.

Using information from the pre-testing, focus group discussions, key informants, model farmers and extension workers in the study area as well as discussions with experts, we selected five coffee attributes to define new coffee variety alternatives.

The questionnaire was translated into the local language (Tigrigna), and a pre-test face-to-face survey was conducted in May 2016. 36 farmers from the study area who were

Table 1. Description of process of developing the Discrete Choice Experiment (DCE) survey.

Stage	Research activity	Period	Description	Purpose
1.	Literature review and semi-structured interviews with key stakeholders in the area	March-April 2016	Identification of coffee attributes, and farming practices in the case study area	Identify relevant attributes to include in the DCE, and sociodemographic and other factors explaining farmers´ choices
2.	Focus groups (5 groups; each with four discussants; N=20), used both to explore and to pre-test a tentative version of the DCE	April-May 2016	Assess farmers' perception towards the coffee attributes and climate change	Identify and refine relevant attributes to include in the DCE exercise, and questions to map factors affecting respondents´ choices
3	Pre-test survey (N =36 face-to-face interviews)	May 2016	Test survey instrument and follow-up questions about the attributes and the credibility of the valuation scenarios/ choice cards	Check whether the choice cards and questions are found to be realistic, acceptable and understandable to the respondents
4.	Final Survey (N = 358 face-to-face interviews)	May-August 2016	Assess preferences of the local people towards different coffee attributes	Conduct the DCE exercise with the selected coffee attributes

engaged in farming activities (not only coffee production) at the time of the survey were randomly selected for the pre-test. During the pretest of the DCE, the choice sets included "quality" and "marketability" attributes, and each choice set had three alternatives and an opt-out option (i.e. none of the alternatives). Each alternative was characterized by five attributes. In the pretest, the respondents reported the choice sets to be too complex. Therefore, we changed each choice set in the final survey to include only two new alternatives and the opt-out option, where the alternatives included four non-monetary coffee attributes and a cost attribute.

Previous studies have shown that the use of labeled alternatives in DCE has a significant effect on individual choices, and could reduce respondents' attention to the actual attributes and make them look only at the labels of the alternatives (Jin, Jiang, Liu, & Klampfl, 2017). Since the goal of this study is to examine preferences for coffee traits, the choice sets comprised the unlabeled alternatives: "Alternative A" and "Alternative B"; and the opt-out alternative "Neither Alternative A nor Alternative B", having no additional cost.

The final survey was conducted from May to August 2016 by seven experienced interviewers who were trained for three days in survey techniques. They conducted face-to-face interviews of a random sample of 358 heads of farming households in the study area. During the interview, interviewers started by explaining the proposed breeding program and possible improvements in the coffee traits/attributes in order to help respondents to prepare for the choice cards. After addressing questions from the respondents, if any, the interviewers proceeded to the DCE. Afterwards, information about the sociodemographic characteristics of respondents were collected.

2.2.2 Design of attributes

The procedure in the final selection of attributes and definition of attribute levels is based on a review of previous studies (Asrat et al., 2010; Wale & Yalew, 2007), and examination of opinions expressed in the carefully crafted focus group discussions that include experienced and model farmers, ordinary farmers (mainly coffee breeders) and agricultural researchers as well as extension workers in the area. The experts on crop breeding and agricultural researchers have hands-on experience and practical knowledge about which coffee attributes are important. Similarly, the discussants reported that they considered the attributes as important for their selection of a particular coffee variety. The additional payment to fund the breeding program to improve the coffee attributes is presented as an extra cost of the seedlings for that particular coffee plant and is included along with the coffee attributes. Thus, the attributes included in the choice sets are: i) yield, ii) weather tolerance, iii) disease resistance, iv) maturity period, and v) extra cost of the seedling. Table 2 provides a description of the attributes and their levels.

Yield refers to the increase in average productivity of a coffee variety in quintal (1 quintal (Q) = 100 kg) per hectare. The improvement in yield has been emphasized by policy makers and development practitioners aiming at increasing farmers′ income and ensuring food security. The yield attribute has three levels: no change (the current yield per ha), and $1/4^{th}$ (one fourth) and $1/3^{rd}$ (one third) increase in productivity. The current yield per ha varies across different production systems and the coffee varieties. The average productivity in quintals per hectare (Q/ha) is 2-3 for forest coffee, 4-5 in semi-forest coffee, 7-8 for garden coffee and 9 for plantation coffee; and the national average is 6-7 Q/ha. The productiv-

Table 2. Attributes and attribute levels, including the "no change" levels of the opt-out option, used in the discrete choice experiment.

Attribute	Description	Attribute levels
Yield	Increased average productivity in terms of yield per hectare of a particular coffee variety	No change*, 1/4th increase, 1/3rd increase
Weather tolerance	Whether the coffee variety is tolerant to drought and frost and gives stable yield in the face of such weather stress factors.	No change*, Drought only tolerant, Drought and frost tolerant
Disease resistance	Whether the coffee variety gives stable yield despite the occurrences of coffee diseases or pest infections in scenarios of no drought and/or no cold weather.	No change*, Moderate disease resistant, Strong disease resistant
Maturity period	The time (in years) the coffee variety needs before giving its first normal yield.	No change*, 3 years, 5 years
Extra Cost per seedling	The additional payment, in Ethiopian Birr (ETB), an individual farmer is expected to pay per seedling	0, 7, 15, 20, 25 ETB

Notes: # ETB = Ethiopian birr; at the PPP conversion factor on 31 December 2016, 1 USD=8.68 ETB.
* "no change" in the opt-out option correspond to a maturity period of approximately 7 years for the traditional coffee varieties. No change to weather tolerance and diseases resistance traits are associated with a little drought and frost tolerance and a little disease resistance, respectively. The opt out traits/attribute levels are not included in constructing the hypothetical choice sets.

ity for selected varieties and hybrid varieties is in the range of 6-17 Q/ha and 15-24 Q/ha, respectively. Increased yield per hectare raises household income and is expected to have a positive effect on farmers´ willingness-to-pay (WTP) for seedlings of a coffee variety.

Weather tolerant and disease resistant traits are associated with the performance of the coffee variety in terms of giving a stable yield. *Weather tolerance* refers to the capacity of the coffee variety to withstand drought and frost, and to give a stable yield year after year. This attribute has three levels: no change (meaning little drought or frost tolerant), drought tolerant, and drought and frost tolerant. *Disease resistance* refers to the resilience and resistance of the coffee variety to diseases and pest infections when there is neither drought nor frost and it gives a stable yield year after year. The disease resistance attribute has three levels: no change (meaning little disease resistant), resistance only to common diseases, and high resistance to common and uncommon diseases. Increased weather tolerance and disease resistance are expected to increase farmers´ WTP for coffee traits.

Maturity period refers to the duration of time (in years) the coffee plant need to fully develop and start giving a normal yield. The maturity period attribute has two levels: five years and three years. An increase in the maturity period of the coffee is expected to have a negative effect on people's wellbeing and their preferences for the coffee variety. The *Cost* attribute is defined as *extra* costs per seedling. The average cost of a coffee seedling in the area at the time of the survey was approximately ETB 5-7.

2.2.3 Experimental design

This study employs an orthogonal main effect experimental design (OMED) to combine attribute levels and create choice sets. In creating the choice sets, we used the R soft-

Figure 1. Example of a choice card as it appeared in the questionnaire in the final survey. The "Neither A nor B" alternative to the right is the opt-out option.

Which of the following coffee varieties do you prefer? Alternative A and Alternative B would entail a cost to your household, while no payment would be required for the "Neither" option

	Alternative A	Alternative B	
Yield	1/4th increase	1/3rd increase	Neither Alternative A nor Alternative B: I prefer none of the new varieties
Weather tolerance	Drought and frost	Drought	
Disease resistance	Disease resistant	Disease resistant	
Maturity duration	3 years	5 years	
Cost per seedling	ETB 5	ETB 20	

I would prefer: Alternative A ____ Alternative B ____ Neither ____

Note: ETB = Ethiopian birr; 1 USD=8.68 ETB in terms of Purchase Power Parity (PPP) corrected exchange rate on December 31st, 2016.

ware version 3.3.2 and adopted the code by Aizaki (2012) to execute the experimental design and randomly assign the choice sets into two blocks. The experimental design creates 16 choice sets, and the two blocks include 8 choice sets each. Figure 1 shows a choice set as it was presented in a choice card to the respondents. The choice tasks put respondents in a hypothetical setting, offering them choice sets comprising two new alternative coffee varieties (presented as "Alternative A" and "Alternative B"), and an opt-out option ("Neither Alternative A nor B"). The two new coffee varieties come at an extra cost of the seedling in order to cover the costs of developing a new variety. The opt-out option has no extra cost of the seedlings as the farmers will then have the traditional coffee variety. The alternatives in the choice sets differ in one or more of the attribute levels.

The respondents are randomly assigned to the two blocks, and asked to choose his or her most preferred alternative in a sequence of eight choice sets. The respondents are subjected to only eight choice sets each, with the aim of attaining a balance between fatigue and learning (Caussade et al., 2005).

Similar to Meyerhoff and Liebe (2009), this study imposed restrictions to avoid unrealistic choice tasks by making the new alternatives have at least one higher attribute level than the opt-out alternative. This avoids new alternatives having inferior values to the opt-out option, but they can have higher extra costs. However, dominant choices created from the experimental design were also presented to the respondents as the removal of irrational or inferior preferences from the choice experiments could affect statistical efficiency (Lancsar & Louviere, 2006). Besides, the presence of new alternatives with higher/lower non-monetary attribute levels but less/equal cost (dominant/dominated alternatives) than other alternatives could help to examine whether respondents pay enough attention to and understand the choice task. Further, having generic alternatives such as "Alternative A" and "Alternative B" can make respondents focus on the attributes/traits rather than the labels we could have put on the alternatives/ coffee varieties.

2.3 Sample characteristics

In the final survey we interviewed 358 farmers residing in the rural areas of Raya Alamata and Raya Azebo districts of Tigray in northern Ethiopia. We applied proportional sampling to give larger quota to districts and villages with larger population and vice versa, and systematic random sampling to select farmers from household head name lists in sub-district offices. According to the most recent Ethiopian Central Statistical Agency census report (CSA, 2007), the total number of households in Raya Alamata and Raya Azebo was 20,532 and 32,360, respectively. Accordingly, the proportion of sampled household heads from the two districts was 60 percent from Raya Azebo and 40 percent from Raya Alamata. The sociodemographic characteristics of the farmers are presented in Table 3.

2.4 Model specification and estimation

The conditional logit model is commonly used to analyze consumer choice behavior based on random utility theory (McFadden, 1974). Conditional logit assumes the idiosyncratic errors to be independently and identically distributed (IID) extreme values, and the tastes for observed attributes to be homogeneous. Evidence shows that individuals exhibit significant heterogeneity in preferences for goods and services (see Alberini & Ščasný, 2013; Allenby & Rossi, 1999; Birol, Karousakis, & Koundouri, 2006). Mixed logit (MIXL) models relax the independence of irrelevant alternative (IIA) assumption of the more restrictive closed-form discrete choice models and allows for heterogeneity of preferences for observed attributes (Hensher & Greene, 2003; McFadden & Train, 2000). In this model, utility U is assumed to be latent, but observed only with the choice Y of alternative j (0, 1, 2) by individual i (i=1, … 358) in choice set t (t=1,2, … 8). A utility function given a choice set t with j alternatives for individual i can be written as;

$$U_{ijt}=\beta_i X_{ijt}+\varepsilon_{ijt}$$

Table 3. Description of sociodemographic variables used to explain the variations in farmers' preferences for the selected coffee traits.

Variable	Mean	Median	Std. Dev.	Definition
Age	43.2	40	13.6	Age of the household head; in years
Family size	5.6	6	2	Total number of family members in the household (including the respondent)
Education	1.8	0	3	Education level of household head; in years
Market	60	60	49.9	The distance to the main market from home; walking time in minutes
Farm size	2.9	3	1.9	The area of the farmed land the farmer owns; in Timad (1 hectare= 4 Timad)
Irrigable land	0.44	-	0.5	Whether the farmer owns irrigable land; 0=No; 1=Yes
Experience	0.28	-	0.47	Whether the farmer has ever managed a coffee farm (now or before); 0=No; 1=Yes

where X_{ijt} is a vector of observed explanatory variables including coffee attributes and sociodemographic characteristics, β_i is a vector of conformable parameters (unknown utility weights) the individual assigns to these variables; and ε_{ijt} is a random term that does not depend on underlying parameters or observed data, with zero mean and IID over alternatives. The utility weight (β_i) for a given attribute is given as;

$$\beta_i=\beta+\delta'_i v_{ij}$$

Where β is a vector of mean attribute utility weights in the population, δ is a diagonal matrix which contains the standard deviation (σ) of the distribution of the individual taste parameters (β_i) around the mean taste parameter (β), and v_{ij} is the individual specific heterogeneity with mean equal to 0 and standard deviation of 1. The MIXL model permits random parameters to vary over individuals, and not observation, in order to measure interpersonal heterogeneity. The vector X_{ijt}, can include 0/1 terms to allow for alternative specific constant (ASC), where ASC takes the value 1 for "Alternative A" and "Alternative B" and 0 for the opt-out option. ASC accounts for the systematic differences in choice patterns between the alternatives. Behaviorally speaking, the ASC parameter reflects the average effect of various components such as endowment effect, status quo bias, omission bias, and the impacts of complexity such as fatigue effects and other unobserved attributes (Boxall et al, 2009; Meyerhoff & Liebe, 2009). The inclusion of an opt-out option can also reflect actual behavioral phenomena by avoiding forced demand, and hence improves the reliability of the welfare measures (Boxall et al., 2009; Veldwijk et al., 2014).

We set the parameters on yield, weather tolerance, disease resistance and maturity period attributes as random and with normal distribution, and the parameter on the cost attribute is set as fixed. A positive sign for significant coefficients of the attributes in the econometric estimation indicates a positive effect of the increase in the respective attribute on farmers' preferences, whereas a negative sign indicates a negative effect of the attribute on their preferences. Statistically significant coefficients on the attributes also enable the calculation of WTP for a change in the attribute. In a utility function linear in its parameters, the marginal WTP equals the negative ratio of the respective coefficient of non-monetary attribute and the coefficient of the monetary attribute (Hensher & Greene, 2011). The WTP estimates presented in Table 4 refer to a marginal, one level change in the attributes. The attributes levels included in this model are presented in Table 2, and the sociodemographic variables are defined in Table 3.

The coefficients in MIXL models are estimated with a simulated maximum likelihood estimation technique. This study used the gmnl-package by (Sarrias & Daziano, 2017) in R software version 3.3.2 to estimate the coefficients on alternative attributes and sociodemographic variables. Since the sociodemographic variables do not vary across choices/observations, their interaction with ASC are included to test whether they explain the observed taste variations across farmers or are random parameters across individuals. Akike information criteria (AIC), Bayesian information criteria (BIC) and likelihood ratio tests are used to compare the goodness of fit of the model and select the model with superior goodness of fit compared to other models. The inclusion of the sociodemographic variables in the MIXL model is used to uncover the factors explaining farmers' preference heterogeneity.

3. Results and Discussions

Standard multinomial logit (MNL) models were estimated first, before proceeding to MIXL models. Table 4 presents the results. Other models such as Scaled-multinomial logit model and generalized multinomial logit model were also estimated; see appendix A-1. The results from the MIXL models show superior fit to the data in this study. In the MIXL estimation, we set the coefficients on the attributes yield, weather tolerance, disease resistant and maturity duration to be random parameters with normal distribution, while the coefficient on the cost of seedlings is fixed in order to use it to compute WTP estimates. The maturity duration and cost of seedlings attributes are continuous variables; while the yield, weather tolerance and disease resistance attributes are categorical.

The coefficient on ASC is significant and positive, implying that farmers prefer the new alternative varieties at some additional cost to the existing varieties that come at no additional cost. Less than two percent of the respondents chose the opt-out option, but none of these respondents protested the proposed coffee variety development program and the changes in traits/attributes. Although the interviewers were trained to avoid experimenter demand effects (Zizzo, 2010), i.e. the respondent trying to please the interviewer by saying what they assumes the interviewer would like to hear, we cannot rule out that this effect might have contributed to the low opt-out percentage.

ASC captures the average effect of all relevant factors that are not included in the model. Thus, farmers´ choice of new improved varieties over the traditional ones seem to be motivated not only by coping with frequent weather changes and occurrence of coffee diseases, but also by the desire for high yield and early maturing traits.

Results from the MIXL model show that the estimated coefficients on yield, weather tolerance, disease resistance and maturity duration are all statistically significant. This implies that any developments in the specified coffee traits have significant effects on farmers' preferences for coffee varieties. The parameter on the yield attribute is interpreted in relation to an increase in productivity per hectare or an increase in farm income resulting from cultivating a coffee variety. The weather tolerance trait enhances resilience against drought and frost, while the disease resistance trait increases resilience against coffee diseases and pest infections occurring under "no drought" and "no frost" weather conditions. Thus, the coefficients on disease resistant and weather tolerant traits can be interpreted as farmers´ preferences for yield stability or resilience to risk of yield loss, and hence is also as an indicator of farmers` risk preferences. The parameter for the maturity period attribute reflects the time preference of farmers. The signs of the coefficients for all attributes/traits are consistent with standard economic theory as farmers prefer increased weather tolerance, higher disease resistance, and higher yield per hectare, but reduced duration of the maturity period and lower extra cost per seedling.

The significant and positive coefficient for the yield attribute implies that farmers prefer high yield coffee varieties to low yield coffee varieties, holding all other things constant. This implies that improvement in productivity per hectare of a coffee variety increases the farmer's preference for this variety. Previous DCE studies of annual crops (Asrat et al., 2010; Kassie et al., 2017) showed farmers to have similar positive preferences for the yield improvement attribute.

Table 4. Results of the MNL model and MIXL models without (MIXL1) and with (MIXL2) sociodemographic determinants of preferences heterogeneity.

	MNL model	MIXL1 model	MIXL2 model
ASC	4.621***	8.750***	6.825***
	(0.220)	(0.572)	(0.600)
Yield high	0.754***	1.078***	0.838***
	(0.065)	(0.117)	(0.231)
Weather tolerant	0.970***	1.292***	1.453***
	(0.067)	(0.135)	(0.284)
Disease resistant	0.929***	1.425***	2.713***
	(0.061)	(0.131)	(0.521)
Maturity duration	-0.452***	-0.548***	-0.665***
	(0.034)	(0.071)	(0.129)
Cost of seedling	-0.044***	-0.058***	-0.065***
	(0.005)	(0.006)	(0.009)
Yield high. Experience			0.028*
			(0.012)
Weather tolerant. Irrigation			-0.001*
			(0.001)
Disease resistant. Education			-0.018*
			(0.009)
Disease resistant. Age			-0.063
			(0.045)
Maturity duration. Education			0.051**
			(0.018)
Maturity duration. Market			-0.005
			(0.004)
Maturity duration. Experience			-0.001*
			(0.001)
N	2860	2860	1869
Log-likelihood	-1765.161	-1594.251	-1131.047
BIC (BIC/N)	3578.073 (1.251)	3315.839 (1.159)	2435.356 (1.303)
AIC (AIC/N)	3542.321 (1.239)	3220.502 (1.126)	2308.094 (1.235)

Note: Standard error in parentheses. ***, ** and * denote significant at the 1, 5 and 10 % level; respectively.

Weather tolerant and disease resistant attributes are associated with the ability of a coffee variety to withstand environmental stressors and to give stable yield. The estimated coefficients for these two attributes are consistently significant and positive. This could imply that farmers are willing to pay more for seedlings with these traits and are thus willing to give up part of their income in order to ensure stable yield. A DCE by Asrat et al. (2010) assessing the trait preferences of Ethiopian farmers for sorghum and teff crop varieties showed that farmers are willingly forego some income or yield to obtain a more stable and environmentally adaptable crop variety. The coefficient on the maturity period is significant and negative, indicating that farmers prefer early maturing coffee varieties over those coffee varieties that take longer to start giving normal yield. Similarly, experimental evidence on rice traits in western Africa showed farmers to be willing to pay for early maturing traits (Dalton, 2004) Note, however, that both Asrat et al. (2010) and Dalton (2004) looked at annual crops, while coffee is a perennial crop.

Policy makers often stress the importance of high yield varieties to meet the growing demand for food, but adoption of high yielding variety technologies is low. Our study shows that farmers are willing to pay more for improving traits associated with yield stability, such as weather tolerant and diseases resistant traits, than for increasing the yield per hectare or early maturity. The magnitude of the coefficients corresponds to the importance the farmers put on the traits. In a related study, Kassie et al. (2017) examined farmers' preferences for drought tolerant maize in rural Zimbabwe, and found that farmers are willing to pay five times more for a variety with a drought tolerance trait than for a variety providing an additional ton of yield per hectare. This implies that farmers are willing to forgo an increase in yield per hectare to get a stable yield on the farm. The subsistence nature of agriculture and escalated poverty in the area might restrain them from adopting a high yield cash crop variety technology with some risk and keep farmers trapped with a low yield and low cost variety technology.

Table 4 also reports the coefficients of sociodemographic factors that can explain preference heterogeneity among the farmers. Heterogeneity around the mean of the taste parameters is consistently apparent with respect to yield, weather tolerance, diseases resistance, and maturity duration traits. Therefore, we included age, education, experience with coffee farming, access to irrigation and distance to market in order to assess the observed sources of variation and to identify factors responsible for the heterogeneity. Note that the models in Table 4 are not directly comparable in the conventional model fit criteria of log likelihood, Akaike Information Criterion (AIC) and Bayesian Information Criterion (BIC); as the number of observations in the model with the sociodemographic factors (MIXL2) is much smaller than in the models without these variables. Although BIC divided by number of observations (BIC/N) is higher in MIXL2, this is not the case for the AIC/N. Thus, we cannot conclude that the inclusion of these sociodemographic factors increases the model fit. We focus on the estimates from the MIXL model since the results demonstrate the presence of preference heterogeneity among the farmers. Education, access to irrigation, and experience of the farmer in coffee farming were found to be the factors that explain variation around the average level of taste preference for the traits. About 28% of the respondents reported having some experience in coffee farming activities, which explains preference variations for high yield and early maturing traits.

Considering the high yield trait, farmers with experience in coffee farming exhibit higher preferences for improvements of yield per hectare than farmers without experience. Some farmers in the study area are replacing low yield coffee varieties with improved coffee varieties, while others are shifting towards cultivation of other more lucrative cash crops such as khat. Farmers with relatively high levels of literacy are found to have lower preferences for disease resistant traits. This finding coincides with Gächter et al (2007) that found increased level of education to decrease loss aversion. On the other hand, farmers with better access to irrigation reveal lower preferences for weather tolerant coffee traits than the farmers who have no access to irrigation. This is as expected as farmers' lack of access to irrigation could increase their vulnerability to drought, and thus their risk aversion.

The coefficient on the maturity duration attribute is negative. A negative significant coefficient on maturity duration indicates that an increase in maturity duration of the coffee variety reduces farmers' preferences for that particular variety. Farmers' years of education reduces the negative effect of increasing maturity duration of late-maturing coffee varieties, whereas coffee farming experience increases the negative effect of increasing maturity duration. The could be explained by farmers´ private discount rate to increase with age and decrease with educational level and literacy, as observed by (Kirby et al., 2002). These days, almost the entire coffee farming area in the study area has been turned into production of khat and other cash crops. Thus, farmers with coffee farming experience tend to be older, and older farmers could have higher private discount rates and thus prefer early maturing traits.

In DCE analysis, the coefficients in themselves have no direct economic interpretation, but the negative ratio of the coefficients of the attribute to the cost coefficient give the marginal WTP estimate for the changes in the attributes (Hensher & Greene, 2003). Positive and negative marginal WTP estimates reflect utility and disutility of the attribute, respectively. The WTP for a change in an attribute level combined with the increment in the attribute level, leaves the deterministic part of the respondent's utility for a profile unchanged (Fiebig et al 2010) Table 5 presents the marginal WTP of the four coffee traits.

Observing the marginal WTP estimates (deferring the heterogeneity, i.e. the MIXL2 model), the farmers are willing to pay more for frost and drought tolerance as well as disease resistance traits, compared to increased yield. The premium is 2-3 times the amount they are willing to pay for a 1/3rd increase in the yield of 1 quintal/ha (1 quintal = 100 kg). This compares well with a similar study of farmers' preference for maize traits in Zimbabwe. Kassie et al. (2017) showed that the value farmers attach to drought tolerance is about five times higher than the WTP they attach to changing a variety. Our results also reflect the difficulties in making inter-annual adjustment in coffee farming practices. These results can explain the prevailing low adoption of high yield varieties by farmers in Ethiopia (Wale & Yalew, 2007).

The coefficient on the maturity period is significant and negative, which implies that an early maturity trait is more preferred to a late maturing trait. The negative sign implies

Table 5. Marginal WTP; in Ethiopian Birr (ETB) (1 USD=8.68 ETB in terms of Purchase Power Parity (PPP) corrected exchange rate on December 31st 2016).

Attributes	WTP Estimates from the MIXL1 model	WTP estimates from the MIXL2 model
ASC	150	105
Yield, high	18	13
Weather tolerant	22	22
Disease resistant	24	42
Maturity period	-9	-10

that farmers are willing to give up part of their income or yield to shorten the waiting period for the full development of the coffee plant and to start harvesting normal yield. In other words, farmers have disutility from a delay in the time it takes for the coffee seedling to give normal yield.

The significant and positive coefficient on ASC implies that other unobservable systematic factors also increase farmers' preferences for new alternative coffee variety over traditional varieties.

To summarize, the WTP results confirms that farmers prefer stable yield varieties (i.e. high disease resistant and weather tolerant traits) to high yield varieties or early maturing varieties, holding all other things constant.

4. Conclusion

Understanding farmers' preferences for coffee traits can help develop policies and breeding programs for new varieties that integrate traits in demand by the farmers, and thus increase farmers' adoption of new varieties. Using a discrete choice experiment, this paper examines farmers' preferences for increased yield, weather tolerance in terms of adaptation to drought and frost, disease resistance, and early maturing traits of Arabica coffee. The results show that farmers are willing to cultivate and pay more for weather tolerant and disease resistant coffee varieties than high yielding and early maturing ones. This indicates that farmers prefer improvements in yield stability traits to traits that maximize yields. Thus, crop-breeding programs aiming for larger uptake of new coffee varieties among farmers in order to increase coffee production should primarily develop weather tolerant and disease resistant varieties and combine them with high yield and early maturing traits.

The trait preferences of smallholder farmers also have implication for *in-situ* versus *ex-situ* conservation of coffee genetic diversity in Ethiopia. Smallholder farmers with no experience in coffee farming will not cultivate and maintain coffee varieties in their fields if yields are unstable, as they prefer the yield stability traits of weather tolerance and disease resistance. Thus, the uptake of varieties with high yield and early maturing traits will be low among farmers in regions without a history of coffee growing. *Ex-situ* conservation programs should therefore give priority to coffee varieties with these and other traits that are less preferred by farmers in order to preserve the full genetic heritage Ethiopian coffee.

Although farmers prefer stable yield to high yield traits, the mixed logit model results show heterogeneity in farmers' preferences for the coffee traits. Farmers with coffee farming experience exhibited higher preferences for high yielding and early maturing coffee traits than those that had no experience in coffee farming. In contrast, farmers with more years of education prefer maturing traits and disease resistant traits less than those with little education. Further, farmers with access to irrigable farmland exhibit lower preferences for weather tolerant traits. This implies that tailoring the improved coffee varieties to the preferences of these different groups of farmers would enhance farmers' adoption of the new varieties. This could make a significant contribution to improving coffee farmers' adaptation and resilience to climate change.

Future research is needed in order to test whether our findings on smallholder farmers' preferences can be generalized to other coffee growing regions in Ethiopia and around the world. Such new stated preference surveys should be based on best practice guidelines;

see Johnston et al (2017). Preferably, similar surveys should be carried out at the same time in different regions in order to better understand what measures are needed for coffee farmers to adapt to climate change impacts.

References

Aizaki, H. (2012). Basic functions for supporting an implementation of choice experiments in R. *Journal of Statistical Software, 50*, 1-24.

Alberini, A., & Ščasný, M. (2013). Exploring heterogeneity in the value of a statistical life: Cause of death v. risk perceptions. *Ecological Economics, 94*, 143-155.

Allenby, G. M., & Rossi, P. E. (1999). Marketing models of consumer heterogeneity. *Journal of Econometrics, 89*(1-2), 57-78.

Asrat, S., Yesuf, M., Carlsson, F., & Wale, E. (2010). Farmers' preferences for crop variety traits: Lessons for on-farm conservation and technology adoption. *Ecological Economics, 69*(12), 2394-2401.

Ayenew, T., GebreEgziabher, M., Kebede, S., & Mamo, S. (2013). Integrated assessment of hydrogeology and water quality for groundwater-based irrigation development in the Raya Valley, northern Ethiopia. *Water International, 38*(4), 480-492.

Bacon, C. (2005). Confronting the coffee crisis: can fair trade, organic, and specialty coffees reduce small-scale farmer vulnerability in northern Nicaragua? *World Development, 33*(3), 497-511.

Baidu-Forson, J., Ntare, B. R., & Waliyar, F. (1997). Utilizing conjoint analysis to design modern crop varieties: empirical example for groundnut in Niger. *Agricultural Economics, 16*(3), 219-226.

Bello, M., Abdoulaye, T., Abdulai, A., Wossen, T., & Menkir, A. (2019). Modeling farmers' willingness to pay for stress tolerance in maize in northern Nigeria: how does the states of gains and losses matter? 2019 Sixth International Conference, September 23-26, 2019, Abuja, Nigeria Paper 295797, African Association of Agricultural Economists (AAAE).

Bertrand, B., Etienne, H., Cilas, C., Charrier, A., & Baradat, P. (2005). Coffea arabica hybrid performance for yield, fertility and bean weight. *Euphytica, 141*(3), 255-262.

Birol, E., Karousakis, K., & Koundouri, P. (2006). Using a choice experiment to account for preference heterogeneity in wetland attributes: the case of Cheimaditida wetland in Greece. *Ecological Economics, 60*(1), 145-156.

Boxall, P., Adamowicz, W. L., & Moon, A. (2009). Complexity in choice experiments: choice of the status quo alternative and implications for welfare measurement. *Australian Journal of Agricultural and Resource Economics, 53*(4), 503-519.

Caussade, S., de Dios Ortúzar, J., Rizzi, L. I., & Hensher, D. A. (2005). Assessing the influence of design dimensions on stated choice experiment estimates. *Transportation Research Part B: Methodological, 39*(7), 621-640.

Coromaldi, M., Pallante, G., & Savastano, S. (2015). Adoption of modern varieties, farmers' welfare and crop biodiversity: Evidence from Uganda. *Ecological Economics, 119*, 346-358.

Dalton, T. J. (2004). A household hedonic model of rice traits: economic values from farmers in West Africa. *Agricultural Economics, 31*(2-3), 149-159.

Dubale, P., & Teketay, D. (2000). *The need for forest coffee germplasm conservation in Ethiopia and its significance in the control of coffee diseases*. Paper presented at the the proceedings of the workshop on control of coffee berry disease in Ethiopia.

FAO (2015). Voluntary guidelines to support the integration of genetic diversity into national climate change adaptation planning: Food and Agricultural Orgnasation of the United Nations, Rome, Italy. 50 pp. ISBN: 978-92-5-108882-1. http://www.fao.org/documents/card/en/c/290cd085-98f3-43df-99a9-250cec270867/

Fiebig, D. G., Keane, M. P., Louviere, J., & Wasi, N. (2010). The generalized multinomial logit model: accounting for scale and coefficient heterogeneity. *Marketing Science, 29*(3), 393-421.

Gächter, S., Johnson, E. J., & Herrmann, A. (2007). Individual-level loss aversion in riskless and risky choices. Discussion Paper no. 2007-02, The Centre for Decision Research and Experimental Economics, School of Economics, University of Nottingham.

Hein, L., & Gatzweiler, F. (2006). The economic value of coffee (Coffea arabica) genetic resources. *Ecological Economics, 60* (1), 176-185.

Hensher, D. A., & Greene, W. H. (2003). The mixed logit model: the state of practice. *Transportation, 30*(2), 133-176.

Hensher, D. A., & Greene, W. H. (2011). Valuation of travel time savings in WTP and preference space in the presence of taste and scale heterogeneity. *Journal of Transport Economics and Policy (JTEP), 45*(3), 505-525.

Jin, W., Jiang, H., Liu, Y., & Klampfl, E. (2017). Do labeled versus unlabeled treatments of alternatives' names influence stated choice outputs? Results from a mode choice study. *PloS one, 12*(8): e0178826. https://doi.org/10.1371/journal.pone.0178826

Johnston, R. J. K. J. Boyle, W. Adamowicz, J. Bennett, R. Brouwer, T. A. Cameron, W. M. Hanemann, N. Hanley, M. Ryan, R. Scarpa, R. Tourangeau, C. A. Vossler (2017). Contemporary guidance for stated preference studies. *Journal of the Association of Environmental and Resource Economists*, 4(2):319–405.

Kassie, G. T., Abdulai, A., Greene, W. H., Shiferaw, B., Abate, T., Tarekegne, A., & Sutcliffe, C. (2017). Modeling preference and willingness to pay for drought tolerance (DT) in maize in rural Zimbabwe. *World Development, 94*, 465-477.

Kirby, K. N., Godoy, R., Reyes-Garcıa, V., Byron, E., Apaza, L., Leonard, W., Pèrez, E, Vadez, V. & Wilkie, D. (2002). Correlates of delay-discount rates: Evidence from Tsimane' Amerindians of the Bolivian rain forest. *Journal of Economic Psychology, 23*(3), 291-316.

Kufa, T. (2012). *Recent coffee research development in Ethiopia.* Paper presented at the Presentation at the "Ethiopian Coffee Export Conference: Strengthening the Legacy of Our Coffee. November 8-9, 2012, Addis Ababa, Ethiopia.

Labouisse, J.-P., Bellachew, B., Kotecha, S., & Bertrand, B. (2008). Current status of coffee (Coffea arabica L.) genetic resources in Ethiopia: implications for conservation. *Genetic Resources and Crop Evolution, 55*(7), 1079-1093.

Lancaster, K. J. (1966). A new approach to consumer theory. *The journal of political economy*, 132-157.

Lancsar, E., & Louviere, J. (2006). Deleting 'irrational'responses from discrete choice experiments: a case of investigating or imposing preferences? *Health Economics, 15*(8), 797-811.

López-Gartner, G., Cortina, H., McCouch, S. R., & Moncada, M. D. P. (2009). Analysis of genetic structure in a sample of coffee (Coffea arabica L.) using fluorescent SSR markers. *Tree genetics & genomes, 5*(3), 435-446.

McFadden, D. (1973). Conditional logit analysis of qualitative choice behavior.

McFadden, D. (1974). Analysis of Qualitative Choice Behavior. Zarembka, P.(ed.): Frontiers in Econometrics. In: Academic Press. New York, NY.

McFadden, D., & Train, K. (2000). Mixed MNL models for discrete response. *Journal of applied Econometrics, 15*(5), 447-470.

Meyerhoff, J., & Liebe, U. (2009). Status quo effect in choice experiments: empirical evidence on attitudes and choice task complexity. *Land economics, 85*(3), 515-528.

Michler, J. D., Tjernström, E., Verkaart, S., & Mausch, K. (2019). Money matters: The role of yields and profits in agricultural technology adoption. *American Journal of Agricultural Economics, 101*(3), 710-731.

Muller, R. A., Berry, D., Avelino, J., & Bieysse, D. (2009). Coffee diseases. *Coffee: growing, processing, sustainable production. A guidebook for growers, processors, traders and researchers*, 495-549.

Ortega, D. L., Waldman, K. B., Richardson, R. B., Clay, D. C., & Snapp, S. (2016). Sustainable intensification and farmer preferences for crop system attributes: evidence from Malawi's central and southern regions. *World Development, 87*, 139-151.

Sarrias, M., & Daziano, R. (2017). Multinomial logit models with continuous and discrete individual heterogeneity in R: the gmnl package. *Journal of Statistical Software, 79*(2), 1-46.

Shiferaw, B., Kassie, M., Jaleta, M., & Yirga, C. (2014). Adoption of improved wheat varieties and impacts on household food security in Ethiopia. *Food Policy, 44*, 272-284.

Siam, M., & Eltahir, E. A. B. (2017). Climate change enhances interannual variability of the Nile river flow. *Nature Clim. Change, 7*(5), 350-354. doi:10.1038/nclimate3273

Smale, M., Bellon, M. R., & Gomez, J. A. A. (2001). Maize Diversity, Variety Attributes, and Farmers' Choices in Southeastern Guanajuato, Mexico. *Economic Development and Cultural Change, 50*(1), 201-225.

Teressa, A., Crouzillat, D., Petiard, V., & Brouhan, P. (2010). Genetic diversity of Arabica coffee (Coffea arabica L.) collections. *Ethiopian journal of applied sciences and technology, 1*(1), 63-79.

Tsegaye, B., Mohammed, A., Shimber, T., Getachew, Y., & Getachew, E. (2014). The Influence of sun drying methods and layer thickness on the quality of lowland Arabica coffee varieties at Gomma I, Southewesten Ethiopia. *Research Journal of Agriculture and Environmental Management. Vol, 3*(11), 547-554.

Vega, F. E., Rosenquist, E., & Collins, W. (2003). Global project needed to tackle coffee crisis. *Nature, 425*(6956), 343-343.

Veldwijk, J., Lambooij, M. S., de Bekker-Grob, E. W., Smit, H. A., & De Wit, G. A. (2014). The effect of including an opt-out option in discrete choice experiments. *PloS one, 9*(11), e111805.

Waldvogel, S. R. (2003). Caffeine - a drug with a surprise. *Angewandte Chemie International Edition, 42*(6), 604-605.

Wale, E., & Yalew, A. (2007). Farmers' Variety Attribute Preferences: Implications for Breeding Priority Setting and Agricultural Extension Policy in Ethiopia. *African Development Review, 19*(2), 379-396.

Ward, P. S., Ortega, D. L., Spielman, D. J., & Singh, V. (2014). Heterogeneous demand for drought-tolerant rice: Evidence from Bihar, India. *World Development, 64*, 125-139.

Zeng, D., Alwang, J., Norton, G. W., Shiferaw, B., Jaleta, M., & Yirga, C. (2014). *Agricultural technology adoption and child nutrition: Improved maize varieties in rural Ethiopia.* Paper presented at the Selected Paper prepared for presentation at the Agricultural and Applied Economics Association's 2014 AAEA Annual Meeting.

Zizzo, D. J. (2010). Experimenter demand effects in economic experiments. *Experimental Economics*, 13(1):75–98.

Appendices

Table A-1. Results from Multinomial logit (MNL), Scaled Multinomial logit (S-MNLl, Mixed logit model with correlated alternatives (MIXL), Mixed logit model without correlation (MIXL_U) and generalized multinomial logit (G-MNL) models.

	MNL	S-MNL	MIXL_U	MIXL	G-MNL
ASC	4.621***	25.530	8.512***	8.392***	9.636***
	(0.220)	(16.563)	(0.559)	(0.512)	(0.813)
Yield high	0.754***	1.907**	1.067***	1.041***	1.198***
	(0.065)	(0.701)	(0.108)	(0.113)	(0.143)
Weather tolerant	0.970***	2.309*	1.421***	1.252***	1.342***
	(0.067)	(0.965)	(0.125)	(0.122)	(0.145)
Disease resistant	0.929***	2.092**	1.366***	1.388***	1.631***
	(0.061)	(0.717)	(0.119)	(0.127)	(0.173)
Maturity duration	-0.452***	-1.406*	-0.734***	-0.493***	-0.593***
	(0.034)	(0.595)	(0.069)	(0.063)	(0.065)
Cost seedling	-0.044***	-0.112*	-0.064***	-0.056***	-0.065***
	(0.005)	(0.046)	(0.006)	(0.006)	(0.007)
Tau		1.410***			0.477***
		(0.323)			(0.091)
Gamma					-0.648
					(0.354)
N	2860	2860	2860	2860	2860
Log-likelihood	-1765.161	-1751.089	-1632.741	-1596.428	-1577.198
BIC	3578.073	3557.888	3345.067	3320.192	3297.651
AIC	3542.321	3516.178	3285.482	3224.855	3190.396

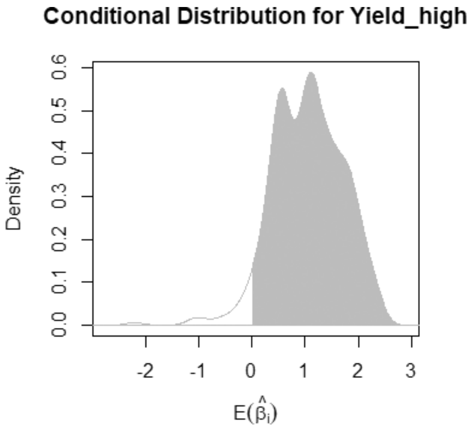
Notes: ***, ** and * denotes significant at the 1, 5 and 10 % level; respectively. Standard error in parentheses.

Table A-2. Standard deviations of the random parameters from mixed logit model results.

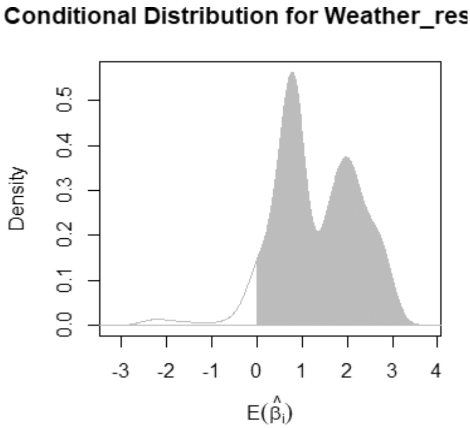
	Estimate	Std. Error	z-value	Pr(>|z|)
Yield high	1.0931	0.1985	5.51	3.7e-08 ***
Weather tolerant	1.3818	0.1906	7.25	4.2e-13 ***
Disease resistant	1.3674	0.2494	5.48	4.2e-08 ***
Maturity duration	0.6452	0.0964	6.69	2.2e-11 ***

Note: ***, ** and * denotes significant at the 1, 5 and 10 % level; respectively.

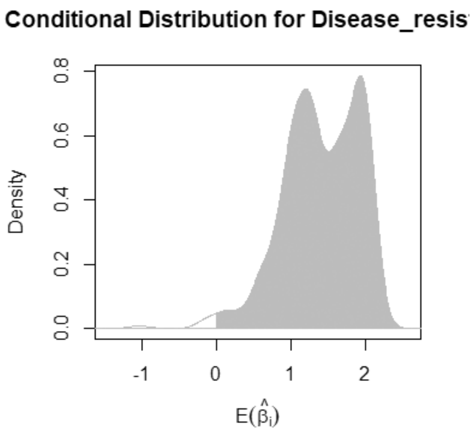
Figure A-1. Distribution of the individuals' conditional mean for the parameters of yield, weather tolerant, diseases resistant and maturity duration. The grey area displays the proportion of individual with positive conditional mean.



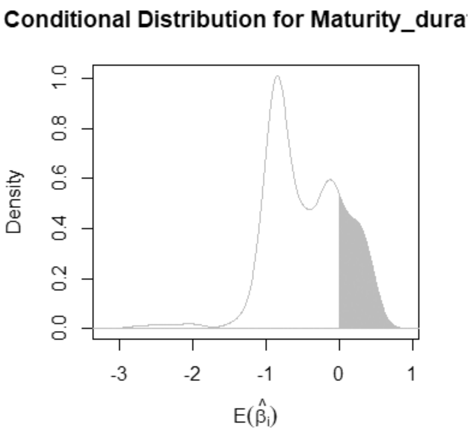
a) Kernel density for yield improvement



b) Kernel density for weather tolerant



c) Kernel density for Disease resistant



d) Kernel density for Maturity duration