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IFPRI Discussion Paper 00938

November 2009

A Latent Class Approach to Investigating Consumer Demand for Genetically Modified Staple Food in a Developing Country

The Case of GM Bananas in Uganda

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ACKNOWLEDGMENTS

We gratefully acknowledge the financial support of the International Food Policy Research Institute and Wageningen University. We would also like to recognize the support provided by Dr. W. Tushemereirwe, leader of the Banana Research Program of the National Agricultural Research Organization (NARO), and other staff members at NARO. We are indebted to Jimmy Katongole, Irene Bayiyana, Martin Segawa, Samuel Etajak, Godfrey Ssengendo, Peter Katongole and Joseph Avon for their help with data collection. Finally, we would like to thank Melinda Smale for her constructive comments and continued support of this study.

ABSTRACT

This study explores consumer acceptance and valuation of a genetically modified (GM) staple food crop in a developing country prior to its commercialization. We focus on the hypothetical introduction of a disease-resistant GM banana variety in Uganda, where bananas are among the most important staple crops. A choice experiment is used to investigate consumer preferences for various banana attributes (bunch size, technology, producer benefit and price), and examine their opinions on GM foodstuff. Choice data come from 421 banana-consuming households randomly selected from three regions of Uganda. A latent class model is used to investigate the heterogeneity in consumers' preferences for banana attributes and to profile consumers who are more or less likely to accept GM bananas. Our results reveal that there is significant heterogeneity in consumer preferences across our sample. GM bananas are valued the most by poorer households located in the rural areas of the Eastern region. These food-insecure households would experience the highest benefits (i.e., welfare gains) from the commercial release of GM bananas. In contrast, urban consumers are less accepting of GM bananas, and they would experience significant welfare losses if GM banana is released. According to our welfare estimates, both the total welfare benefits acquired by the gainers, and the total welfare losses borne by the losers of this technology are significant and large. These results suggest the need for further investigation of the overall welfare effects of the introduction of GM bananas on the Ugandan society as a whole.

Keywords: genetically modified bananas, consumers, choice experiment, latent class model, preference heterogeneity, Uganda

1. INTRODUCTION

Bananas are a major staple crop in Uganda; they occupy over a third of the cultivated area for staple crops in the country (NARO 2001), are produced and consumed by over 7 million Ugandans, and contribute to household incomes, food security and nutritional security. Most of the banana varieties grown in Uganda are endemic to the East African highlands and are dominated by the major use class of cooking bananas (NARO 2001). Although bananas are grown primarily as a subsistence crop, their consumption is not limited to rural areas; each day, 65 percent of urban consumers have a meal that includes cooking bananas (Clarke 2003).

Cooking bananas are highly susceptible to diseases, especially black sigatoka (Nowakunda et al. 2000) and bacterial wilts (Tushemereirwe et al. 2003). This disease susceptibility prompted national researchers to adopt a long-term breeding strategy of using conventional and genetic engineering (GE) methods to introduce resistance. However, the high-yield varieties of cooking bananas proved to be sterile, slowing their improvement through conventional breeding (Ssebuliba et al. 2006). Since such major biotic constraints are not easily addressed through conventional breeding and management practices, recent efforts have involved the use of GE methods to insert resistance traits into selected banana planting materials. Unlike conventional breeding, GE strategies improve agronomic traits (e.g., disease and pest resistance) by inserting genes into host varieties without altering other production and consumption attributes (e.g., cooking quality) (Kikulwe et al. 2007).

Although a genetically modified (GM) banana has yet to be approved for commercialization in Uganda, producers, consumers, and other actors along the value chain need to prepare for the future release of such varieties. Members of the public sector (e.g., the Ministry of Agriculture, Animal Industries and Fisheries; extension workers; etc.) and the private sector (e.g., suppliers of seeds and other agricultural inputs) will need to devise strategies aimed at introducing, disseminating and marketing the new technology. Simultaneously, policy-makers (regulators) will need to develop and adopt a regulatory process that will ensure a high degree of safety without imposing too-stringent biosafety measures that might limit the accessibility of this technology. To ensure a balanced approach to decision-making, the literature suggests that policy-makers should consider all benefits and costs, including opportunity costs and the issue of irreversibility (Wesseler 2009).

In the present study, we look at a hypothetical GM banana variety that may offer potential benefits to banana producers compared to local bananas. We examine how consumers in a developing country with varied or scant information about GM technology (in this case, Uganda) might react towards a GM banana variety that offers clearly stated economic benefits to producers. We use a stated preference technique, namely the choice experiment (CE) method, to investigate consumer preferences for various banana attributes, including bunch size, type of biotechnology (GM or traditional), impact on the welfare of producers, and price. The CE data come from 421 banana-consuming households located in rural and urban areas, and are analyzed using a latent class model (LCM), which enables simultaneous identification of the characteristics that differentiate banana-consuming households and the values that these consumers derive from the tested banana bunch attributes.

This study includes two major contributions to the literature. First, Paarlberg (2008) has argued that the negative attitudes of urban elites in African countries towards GM crops can be explained by their trending relatively closer to the European view on GM food versus the view of rural people in their own country. The inclusion of both rural and urban households in the present study allows us to test whether or not the preferences of urban households differ from those of rural households. Second, this study includes welfare benefits for producers as one of the tested attributes. Producer benefits are often absent from studies on consumer preferences towards GM food. We expect that the inclusion of these benefits in our analysis will have a positive effect on consumers' preferences, in a manner similar to the results reported by Gaskell et al. (2006) and Loureiro and Bugbee (2005).

The next section discusses the theoretical framework of the CE method and the LCM, and explains the CE design and application. Section III describes the data. Econometric results are reported and discussed in Section IV. The last section draws conclusions and discusses policy implications.

2. CHOICE MODELING APPROACH

Theoretical Framework

The CE approach is theoretically grounded in Lancaster's model of consumer choice (Lancaster 1966), which proposed that consumers derive satisfaction not from the goods themselves, but from the attributes they provide. The CE method also has an econometric basis in models of random utility (Luce 1959; McFadden 1974), which integrate behavior with economic valuation. In the CE approach, the utility of a choice is comprised of both a deterministic component and an error component that is independent of the deterministic part and follows a predetermined distribution. The error component implies that predictions cannot be made with certainty; choices made among alternatives will be a function of the probability that the utility associated with a particular option is higher than that associated with other alternatives (Hensher, Rose, and Greene 2005)

When estimating preferences, the heterogeneity of the preferences in the sample should be accounted for through the use of an appropriate model. Accounting for preference heterogeneity enables unbiased estimation of individual preferences, and hence enhances the accuracy and reliability of demand, marginal welfare and total welfare estimations (Greene 2008). Furthermore, accounting for heterogeneity enables the formulation of policy recommendations that take equity concerns into account. Information about who will be affected by a policy change and the aggregate economic value associated with such change is necessary for the crafting of efficient and equitable policies (Boxall and Adamowicz 2002).

A number of alternative models have been developed to account for heterogeneity, including the covariance heterogeneity (CovHet) model (Colombo, Hanley, and Louviere 2009), the random parameter logit (RPL) model (McFadden and Train 2000; Train 1998; Greene and Hensher 2003; Rigby and Burton 2005), and the latent class model (LCM) (Swait 1994; Louviere, Hensher and Swait 2000). Colombo, Hanley and Louviere (2009) provide a detailed comparison of these models for integrating and explaining preference heterogeneity in CEs. The LCM has been successfully used to identify the sources of heterogeneity at the segment (or group) level, whereas the CovHet and RPL models capture heterogeneity at the individual level. Investigation of heterogeneity at the segment level would be most policy-relevant when assessing the welfare impact of the introduction of a technology (such as a GM food/crop) on different segments of the population (see e.g., Hu et al. 2004; Kontoleon and Yabe 2006; Birol, Villaba, and Smale 2009).

The LCM casts heterogeneity as a discrete distribution by using a specification based on the concept of endogenous (or latent) preference segmentation (Wedel and Kamakura 2000). The approach depicts a population as consisting of a finite and identifiable number of segments or groups of individuals. Preferences are relatively homogeneous within segments, but differ substantially across segments. The number of segments is determined endogenously by the data. The slotting of an individual into a specific segment is probabilistic, and depends on the social, demographic, and economic characteristics of the respondents, as well as their knowledge pools, perceptions and attitudes. Furthermore, respondent characteristics indirectly affect the choices through their impact on segment membership.

An increasing number of studies have used this approach to estimate farmers' and consumers' preferences for various agricultural technologies and foodstuffs. For example, Scarpa et al. (2003), Ouma, Abdulai, and Drucker (2007), and Ruto, Garrod, and Scarpa (2008) employed this model for the valuation of livestock attributes; Hu et al. (2004), and Kontoleon and Yabe (2006) used it to investigate consumer preferences for GM food; and Birol, Villaba, and Smale (2009) used it to examine farmer preferences for agrobiodiversity conservation and GM maize adoption.

In the LCM used herein, the utility that consumer *i,* who belongs to a particular segment *s,* derives from choosing banana bunch alternative $j \in C$ can be written as:

$$U_{ij/s} = \beta_s X_{ij} + \varepsilon_{ij/s}, \tag{1}$$

where X_{ij} is a vector of attributes associated with banana bunch alternative *j* and consumer *i,* and β_s is a segment-specific vector of taste parameters. The differences in β_s vectors enable this approach to capture the heterogeneity in banana bunch attribute preferences across segments. Assuming that the error terms are identically and independently distributed (IID) and follow a Type I (or Gumbel) distribution, the probability of alternative *j* being chosen by the i^{th} individual in segment *s* is then given by:

$$P_{ij/s} = \frac{\exp(\beta_s X_{ij})}{\sum_{h=1}^{C} \exp(\beta_s X_{ih})}. \tag{2}$$

M* is a segment membership likelihood function that classifies the consumer into one of the *S* finite number of latent segments with some probability, P_{is}. The membership likelihood function for consumer *i* and segment *s* is given by $M_{is}^* = \lambda_s Z_i + \xi_{is}$, where *Z* represents the observed characteristics of the household, such as their social, economic, and demographic characteristics, as well as their knowledge, attitudes and perceptions. Assuming that the error terms in the consumer membership likelihood function are IID across consumers and segments, and follow a Gumbel distribution, the probability that consumer *i* belongs to segment *s* can be expressed as:

$$P_{is} = \frac{\exp(\lambda_s Z_i)}{\sum_{k=1}^{S} (\lambda_k Z_i)}, \tag{3}$$

where $\lambda_k (k = 1,2,...S)$ are the segment-specific parameters to be estimated. These denote the contributions of the various consumer characteristics to the probability of segment membership. A positive (negative) and significant λ implies that the associated consumer characteristic, Z_i, increases (decreases) the probability that the consumer *i* belongs to segment *s*. P_{is} sums to one across the *S* latent segments, where $0 \le P_{is} \le 1$.

By bringing equations 2 and 3 together, we can construct a mixed-logit model that simultaneously accounts for banana bunch choice and segment membership. The joint unconditional probability of individual *i* belonging to segment *s* and choosing banana bunch alternative *j* can be given by:

$$P_{ijs} = (P_{ij/s}) * (P_{is}) = [\frac{\exp(\beta_s X_{ij})}{\sum_{h=1}^{C} \exp(\beta_s X_{ih})}] * [\frac{\exp(\lambda_s Z_i)}{\sum_{k=1}^{S} \exp(\lambda_k Z_i)}]. \tag{4}$$

Choice Experiment Design

The first step in CE design is defining the banana bunch in terms of its attributes and the levels taken by these attributes. We identified the most important banana bunch attributes and their levels by consulting experts and agricultural scientists at the National Banana Research Program of the National Agricultural Research Organization (NARO), and also by drawing on the results of informal interviews with consumers, and previous work on banana attributes in Uganda (Smale and Tushemereirwe 2007; Edmeades 2003; Nowakunda et al. 2000). The selected attributes, their levels, and their analytic coding are reported in Table 1.

Table 1. Attributes, their definititions, levels, and coding

Attribute	Definition	Levels	Coded using
Bunch size	The average size of a banana bunch at harvest	Small Medium Large	Dummy variables
Benefit	The magnitude of the expected increase in the incomes of banana producers	None Medium Large	Dummy variables
Biotechnology	The type of biotechnology used to produce the banana planting material	Traditional GM	Dummy variables
Price	Hypothetical percentage change in price of a banana bunch	70, 85, 100, 115, 130, 140	Actual values

Note: Underlined levels indicate the status quo.

The first attribute, bunch size, represents the average size of a banana bunch at the time of sale, and varies from small (10 kg), medium (20 kg) to large (30 kg). The majority of the banana bunches currently sold in Uganda (64 percent) are small, as they arise from traditional varieties that are endemic to Uganda (Edmeades 2007).

The second attribute, economic benefits to producers, was included in the CE to test the hypothesis that in addition to experiencing economic benefits related to the quality/quantity of the private good (i.e., the bananas), consumers may derive benefits from social and economic factors, such as higher incomes for producers (Portney 1994). Recent CE studies found that respondents in both developed and developing countries derive benefits from knowing that others are employed, earn higher incomes, or have better livelihoods outcomes (e.g., Othman, Bennett, and Blamey 2004; Bergmann, Hanley, and Wright 2006; Bergmann, Colombo, and Hanley 2008). In addition, a portion of the urban consumers surveyed were one generation away from being farmers and/or had banana-producing relatives in the countryside, while the majority of rural consumers were banana producers (please see section IIIA below). Therefore, we would expect that respondents would derive positive values from this attribute, whether due to altruistic reasons or self-interest.

The third attribute represents the type of biotechnology used to produce the banana planting material. Article 2 of the Convention on Biological Diversity defines biotechnology as "any technological application that uses biological systems, living organisms, or derivatives thereof, to make or modify products or processes for specific use." This definition encompasses both traditional and modern biotechnology. Traditional biotechnology may include the products of tissue culture, micro-propagation, or various strategies used to eliminate disease, while modern biotechnology involves the use of GE techniques, such as DNA diagnostic probes, recombinant DNA, functional and structural genomics, and other methods for genetic modification (Falck-Zepeda 2008). Currently, most banana-producing households in Uganda grow local cultivars of East African highland cooking bananas, which are bred through the use of traditional biotechnology. In contrast, GM cooking bananas bred through the application of modern biotechnology have not yet entered the market. During data acquisition, special care was taken to clearly explain the type of biotechnology used to produce the banana planting materials in question. The explanation was supported by diagrams and photos[1].

[1] The utilized survey materials are available from the authors upon request.

The last attribute, price, portrays hypothetical percentage changes in the price of a banana bunch. This attribute is included in order to estimate consumers' willingness to pay (WTP) a premium or willingness to accept (WTA) a discount based on the other attributes, i.e., the bunch size, the magnitude of benefit, and the biotechnology type. We use percentage change in price instead of fixed prices because the price of banana bunches varies across regions and markets, and even within markets.

Using experimental design methods, the banana bunch attributes and their levels were combined into choice sets. First, a full factorial design including all possible unique banana bunch profile combinations was used to generate possible choice sets. Then, statistical design methods (see Louviere et al. 2000; Kuhfeld 2004; Johnson et al. 2007) were used to structure the presentation of the attribute levels within the choice sets. Following Johnson et al. (2007) and Kuhfeld (2004), a D-Optimal experimental design was constructed with only the main effects (using SAS software). A fraction of the full factorial design was used to construct an efficient design with 16 choice sets, in which each level occurred once in each attribute and choice set. During the survey, each consumer was presented with 16 choice sets, each containing two banana profiles (A, B) and an option to "opt out" by selecting neither of the presented banana profiles. Choosing "opt out" meant that the consumer would purchase his/her current variety.

The data were coded according to the attribute levels (Table 1). The first three qualitative attributes (bunch size, magnitude of benefit, and biotechnology type) were coded to measure the nonlinear effects in the banana bunch attribute levels. Three-leveled attributes were coded as two dummies (e.g. medium and large) using the status quo level as the base. Therefore, the estimated coefficients for medium and large levels indicate the consumers' valuation of the change from the status quo level to the higher utility levels. The price attribute was entered in cardinal form. The CE conducted in this study is generic; therefore, the alternative specific constant (ASC) equaled 1 if either option A or B was chosen, and 0 if the respondent chose the status quo (Louviere et al. 2000). A relatively more negative and significant ASC indicates a higher propensity of consumers to choose the status quo. Based on economic theory and previous studies on bananas in Uganda, it can be expected a priori that consumer utility will increase with banana bunch size and decrease with banana bunch price. The direction of the impact of the benefit and GM attribute levels on consumer utility, however, cannot be predicted a priori.

3. DATA

Study Sites and Sample Characteristics

The target population included households residing in the Eastern, Central and Southwestern regions of Uganda. The CE survey was implemented through face-to-face interviews conducted in July and August 2007. The sample was drawn using a multistage sampling procedure, and stratified into rural and urban consumers. A great majority of rural consumers in Uganda are banana producers, although the proportion of household banana consumption met by the household's own production may vary across rural households; some rural households may choose to grow only for home consumption, with or without a deficit, while others may produce bananas for both household consumption and sale in local and/or urban markets. In contrast, while some urban Ugandan households may produce bananas, the great majority are net banana consumers. The inclusion of both rural and urban consumers in this study is intended to begin examining the preferences expressed by banana consumers across the spectrum of banana production for own consumption.

The primary sampling unit (PSU) was the sub-county for rural areas and the division for urban areas. Eleven PSUs were selected: seven in rural areas and four in urban areas. This selection was based on the distribution of the Ugandan population. The 2002 Uganda census indicated that only 12.3 percent of the population resided in urban areas, such as cities, municipalities, and town councils. The regions selected for sampling contained over 90 percent of the urban population (UBOS 2006). The secondary sampling unit was the community. At the sub-county/division level, two parishes were randomly selected from each PSU. In each parish, one community was drawn using a systematic random sampling criterion with a random start. Urban communities were sampled from the three main cities (Kampala, Mbarara and Jinja); Three communities were sampled from Kampala, which is the capital and most densely populated city, while two communities each were sampled from Mbarara and Jinja. Within each community households were randomly selected from the community level household lists. If the targeted respondent was unavailable or uninterested in participating, the next randomly selected household on the list was chosen to ensure that the desired sample size was realized. A total sample size of 500 households was within the project budget and time constraints. The overall response rate was high (84.2 percent; 421 households), largely due to the face-to-face nature of the survey instrument.

Three types of data were collected with the survey instrument. The first two types included information on the respondents' observed characteristics (vector Z). First, each respondent was asked about his/her knowledge, attitudes and perceptions regarding GM crops and food. Second, the enumerators collected social, demographic, and economic information on the households, including the characteristics of the banana purchase decision-maker(s) and other members of the household. The third data type consisted of the responses to the CE. Prior to the presentation of the 16 choice sets, respondents were told the context in which choices were to be made, and each attribute was described carefully, simply and thoroughly, to ensure uniform comprehension of the attributes and their levels. The respondents were reminded that there were no right or wrong answers, and that the interviewers were only interested in their opinions. The social, demographic and economic characteristics of the sampled banana-consuming households are presented in Table 2.

Table 2. Comparison of consumer characteristics and population statistics

Characteristic	Sample statistics [a]	Population statistics [b]
	Mean	
Age of the household head (years)	40.8 (15.4)	
Household head's formal education (years)	7.2 (4.5)	
Total number of household members	6.1 (3.3)	5.2
Total monthly household income (UGX)[c]	194748.8 (351179.0)	170891
	Percent	
At least one member employed off-farm	53.2	47.0
Proportion of households in the Central region	43.0	
Proportion of households in the Eastern region	28.5	
Proportion of households in the Southwestern region	28.5	
Proportion of households in rural areas	66.7	87.7
Proportion of households in urban areas	33.3	12.3
Proportion of banana-growing households	80.3	
Proportion of banana-buying households	58.9	
Proportion of households with heads in the highest age group (26-49)	62.0	59.0
Proportion of households in which head has at least secondary education	38.0	26.4

Sources. [a] Authors' survey of consumers; [b] UBOS 2006.
Notes. The numbers in parentheses are the standard deviations.
[c] The exchange rate (between July and August 2007) was US $1 = UGX 1750.

Nearly half of the sampled households were located in the Central region, while the Eastern and the Southwestern regions shared the rest of the sample equally. Two-thirds of the sampled households were located in rural areas compared to one-third in urban areas. The respondents' average age was 41 years, with a mean formal education equivalent to primary seven, which is the last level of mandatory education in Uganda. The average household size of the sampled banana-consuming households was six members. On average, 53 percent of the sampled households had at least one household member working off-farm, and the average household income was about UGX 195,000 (US$111) per month. As sampled, the total household income included both agricultural sales income and non-agricultural income (e.g., formal and self-employment wages and remittances).

The majority of the surveyed households (over 80 percent) grew bananas, and more than half of the banana-growing households (51 percent) were self-sufficient in banana consumption. Roughly 60 percent of the sampled households bought bananas to supplement their production; of them, approximately half (49 percent) purchased bananas from the market. Although urban consumers are generally considered to be solely consumers, close to half of the sampled urban households (49 percent) also produced bananas.

Households that were strictly banana consumers were more common in the urban sample (51 percent) compared to the rural sample (4 percent).

Comparing the socioeconomic characteristics of the sample with published statistics for the Ugandan population (UBOS 2006) reveals some differences. The sampled households have older and better-educated household heads, a larger than average household size, a higher proportion of off-farm employment, and (related to this) a higher monthly average household income compared to the population statistics. This can be explained by the fact that in this study we have oversampled from the urban areas, where income, education and off-farm employment levels are higher.

Consumers' Perceptions of, and Attitudes towards GM Crops and Food

Consumers were asked a series of questions aimed at assessing their knowledge, attitudes and perceptions (KAP) regarding GM crops and food, particularly GM bananas (Table 3). To investigate the underlying structure of the KAP data, we conducted a factor analysis of consumers' answers, looking for variables that "factored" well together and had notable relative loading magnitudes in absolute terms. Three factors were identified. The first factor, termed the "benefit KAP," had high loadings on questions related to the potential benefits of GM crops. This factor captures the tendency of a consumer to support a GM crop based on its potential benefits (e.g., price, nutritional quality, decreased chemical use, and taste). The second factor, called the "food-environment risk KAP," had high loadings on statements that reflected consumer concerns on food and environmental safety, including the impact of GM foods or human interference with nature on the status of food and environmental safety. The third factor, called the "health risk KAP," had high loadings on health safety and reflects concerns over the long-term (but as yet unknown) effects of GM food on health and food safety.

Indices were created for the three factors by calculating the factor scores for each household in the sample; this yielded the benefit KAP index (BKAPI), the food-environment risk KAP index (FKAPI), and the health risk KAP index (HKAPI). For BKAPI, higher positive values indicate a greater preference for GM food and crops, particularly GM bananas. In contrast, higher positive values for FKAPI and HKAPI indicate higher levels of concern over food-environment safety and health risks, respectively.

Table 3. Factor analysis loadings for consumers' answers to KAP questions

KAP statements (item contents) were obtained using a 5-point Likert scale, as follows: 1. Strongly disagree; 2. Disagree; 3. Neither agree nor disagree; 4. Agree; 5. Strongly agree.	Factor loading		
	Benefit KAP	Food-environment risk KAP	Health risk KAP
1. I would buy GM banana bunch if it was sold at the same price as a non-GM banana bunch, but was much more nutritious.	0.73	-0.16	-0.30
2. I would buy a GM banana bunch if it was sold at the same price as a non-GM banana bunch, but tasted better.	0.70	-0.17	-0.32
3. I would buy a GM banana bunch if it was sold at the same price as a non-GM banana bunch, but was produced with fewer pesticides.	0.57	-0.17	-0.29
4. I would buy a GM banana bunch if it was cheaper than a non-GM banana bunch.	0.56	-0.24	-0.31
5. If the majority of the Ugandan people are in favor of GM food, it should be legalized.	0.49	0.16	-0.13
6. I would buy a GM banana bunch if it were more expensive than a non-GM banana bunch.	0.34	-0.21	-0.11
7. Information about food safety and nutrition on food labels can be trusted.	0.27	0.14	-0.15
8. The government effectively monitors the correct use of GE in the medical, agricultural and other sectors.	0.24	-0.21	-0.05
9. I think the additives in food are not harmful to my health.	0.24	0.12	-0.07
10. The risks associated with GM food (if any) can be avoided.	0.18	0.10	-0.08
11. When humans interfere with nature, disastrous consequences result.	0.05	**0.61**	0.07
12. Among the risks we presently face, those impacting food safety are very important.	-0.03	**0.55**	-0.18
13. If something went wrong with GM food, it would be a global disaster.	0.00	**0.51**	0.22
14. The government should spend more money to increase food safety.	0.29	**0.50**	0.05
15. Humans are harshly abusing the environment.	0.02	**0.50**	0.17
16. Pesticides and fertilizers are dangerous to our environment.	-0.11	**0.40**	0.10
17. We can only eradicate the diseases and pests that attack crops by using GM technology.	0.26	-0.32	0.02
18. Harmful environmental effects of GM crops are likely to appear in the distant future.	0.18	0.11	**0.66**
19. Harmful human health effects of GM foods are likely to appear in the distant future.	0.15	0.08	**0.62**
20. Even though GM food may have advantages, it is basically against nature.	-0.05	0.13	**0.41**
21. Eating GM food would harm me and my family.	-0.08	-0.07	**0.41**
22. GM technology should not be used even for medicinal purposes.	-0.11	-0.12	0.36
Percent of variance explained (93%)	36	30	27
Eigenvalues [a]	3.29	1.86	1.22

Note. Loadings shown in bold are values of 0.4 and above. [a] The appropriate solution had all three factors with Eigenvalues above 1.

4. RESULTS

Latent Class Model

The best-fitting LCM includes BKAPI, consumer location, consumer age, whether or not the consumer grows bananas, and whether or not the consumer is a self-sufficient grower[2]. The model introduced above is estimated for up to five segments. The log likelihood, ρ^2, Bozdogan Akaike Information Criterion (AIC3) and Bayesian Information Criterion (BIC) statistics for the models are reported in Table 4.

Table 4. Criteria for determining the optimal number of segments

Number of segments	Number of parameters	Log likelihood (LL)	ρ^2	AIC3	BIC
1.	7	-5366.391	0.273	10753.782	5401.089
2	19	-4180.995	0.433	8421.990	4278.011
3	31	-4180.995	0.433	8460.990	4341.072
4	43	-4180.995	0.433	8499.990	4404.132
5	55	-4180.995	0.433	8538.990	4467.193

Notes. The sample size is 20,208 choices from 421 consumers (N). Equations: ρ^2 is calculated as 1-(LL)/LL(0); AIC3 (Bozdogan AIC) as (-2LL+3P); and BIC (Bayesian Information Criterion) as –LL+(P/2)*ln(N).

Determination of the optimal numbers of segments requires a balanced assessment of the statistics reported in Table 4 (Louviere et al. 2000; Wedel and Kamakura 2000; Andrews and Currim 2003). The log likelihood decreases (improves) and ρ^2 increases as more segments are added; both level off after the second segment, indicating the presence of multiple segments in the sample. The BIC and AIC3 are minimized at segment two. As expected, the four criteria improve as more segments are added, but the marginal improvement diminishes after the second-segment model, indicating that a model with two segments is the optimal solution in this empirical application.

The results of the two-segment LCM are shown in Table 5. The first panel of Table 5 presents the utility coefficients associated with the banana bunch attributes, while the second panel gives the coefficients for segment membership. The latter are normalized to zero, permitting us to identify the remaining coefficients of the model (Boxall and Adamowicz 2002). The utility coefficients (Table 5, first panel) show that all of the tested attributes are significant determinants of banana bunch choice for both segments. The relative magnitudes of the three-level attributes are as expected a priori, in that consumers in both segments prefer large over medium attribute levels for both benefits and the banana bunch attributes. However, the attribute rankings and the direction of the impact on utility (positive or negative effect) differ between the two segments. In line with economic theory, members of both segments prefer banana bunches with lower prices. For segment one, the ASC is positive and significant, indicating that these consumers prefer the presented banana profiles (A or B) over the status quo. For segment two, however, the ASC is negative and significant, indicating that the members of this segment prefer the status quo.

[2] Consumer characteristics are tested for possible multicollinearity using Variance Inflation Factors (VIF; Maddala 2001).VIF are calculated by running "artificial" ordinary least squares regressions using each of the independent variable as the "dependent" variable, with the remaining variables as the independent variables. None of the five consumer characteristics examined herein exhibit multicollinearity.

Table 5. Two-segment LCM estimates for banana bunch attributes

Variable	Segment 1: Potential GM banana consumers	Segment 2: Potential GM banana opponents
	Utility function: banana bunch attributes	
	Coefficient	
ASC	2.41*** (0.14)	-0.95*** (0.14)
Bunch size: medium	0.35***(0.02)	0.57*** (0.11)
Bunch size: large	0.49***(0.02)	0.84*** (0.12)
Benefit: medium	0.13***(0.02)	-0.32** (0.13)
Benefit: large	0.21***(0.02)	-1.13*** (0.17)
GM biotechnology	0.48*** (0.03)	-0.94*** (0.11)
Price	-0.01***(0.001)	-0.02*** (0.004)
	Segment membership function: consumers' characteristics	
	Coefficient	
Intercept	2.55***(0.84)	
Location (Urban=1)	-0.87** (0.50)	-
BKAPI	0.42**(0.18)	-
Age	-0.02**(0.01)	-
Self-insufficient	1.18**(0.53)	-
Grows bananas	1.02**(0.61)	-
Log likelihood	-4180.995	
ρ^2 (pseudo R^2)	0.4333	
Sample size	20208	

Note. The numbers shown in parentheses are the standard errors.
* Significant at the 10% level.
** Significant at the 5% level.
*** Significant at the 1% level.

For segment one, the utility coefficients reveal that the most important attribute is banana bunch size (large), followed by GM biotechnology and large benefits for producers. The membership coefficients for segment one indicate that these consumers are more likely to live in rural areas, grow bananas but are not self-sufficient, and have higher BKAPI values. We have labeled this segment "*potential GM banana consumers"* because consumers in this segment derive substantial utility from the GM biotechnology attribute.

Consumers in the second segment, in contrast, rank the attributes differently. The attribute "large benefits for producers" has the largest absolute size, indicating that this attribute is the most important determinant of banana bunch choice, followed by the attributes for GM biotechnology, and large bunch size. Both the large benefit and GM biotechnology attributes exhibit negative signs, revealing that consumers in this segment prefer bunches that do not generate large benefits for producers, are produced with traditional technology, and are large in size. The membership coefficients for segment two can be implicitly interpreted by comparison to the signs of the statistically significant parameters estimated for the other segment. Consumers with a greater dislike of GM foods and crops (lower BKAPI) are more likely to belong to this segment, as are consumers who: live in urban areas; don't grow bananas; are older; and/or are self-sufficient growers. Segment two is labeled "*potential GM banana opponents,"* since these consumers derive significant disutility from the GM biotechnology and benefit attributes.

Characterization of the Segments

The relative size of each segment is calculated by inserting the estimated coefficients into equation (3), and using it to generate a series of probabilities that a given consumer belongs to a given segment. Consumers are then assigned to a segment based on the larger of the two probability scores. Using this procedure, we find that 58 percent of the sample belongs to the first segment, and 42 percent to the second. Descriptive statistics for the characteristics of each segment are given in Table 6.

Table 6. Characteristics of consumers belonging to the two segments

Consumer characteristics	Segment 1: Potential GM banana consumers (N=245)	Segment 2: Potential GM banana opponents (N=176)
	Mean	
Age***	36.82 (13.27)	46.28 (16.32)
Household size**	6.42 (3.30)	5.67 (3.20)
Banana acreage (ha)	0.46 (0.72)	0.44 (0.71)
Household monthly income [a]***	143280.0(251506.4)	266395.8(444362.2)
Benefit index (BKAPI)***	0.30 (0.50)	-0.36 (1.11)
Food and environment index (FKAPI)**	-0.09 (0.89)	0.09 (0.80)
Health index (HKAPI)***	-0.11 (0.81)	0.11 (0.89)
	Percent	
Location, urban =1***	15.51	57.95
Gender, female=1	40.0	47.72
Employed***	46.94	61.93
Residing in the Central region	40.82	46.02
Residing in the Eastern region***	36.32	17.61
Residing in the Southwestern region ***	22.86	36.36
College or university education***	5.71	15.34
Grows bananas***	93.06	62.5
Self-sufficient (self-insufficient = 1)***	66.94	47.72

Note. The numbers shown in parentheses are the standard deviations.
[a] Exchange rate (between July and August 2007) was US $1 = UGX 1750.
* Significant at the 10% level.
** Significant at the 5% level.
*** Significant at the 1% level.

The *potential GM banana consumers* are located mainly in rural areas; moreover, significantly larger and smaller proportions of the households reside in the Eastern and Southwestern regions, respectively, compared to the *GM banana opponents*. Although more households in the first segment (proportion-wise) are located in the Central region, the difference is not statistically significant. This apparent trend may be associated with the high incidences of pests and diseases in this region, as well as high population pressures, which both lead to inadequacies of the banana supply for rural areas of the Eastern and Central regions. Consumers from these supply-deficit regions are more likely to favor the introduction of a biotechnology that may help alleviate pest and disease problems, leading to higher banana productivity and higher levels of supply. As expected, respondents in this *potential GM banana consumer* segment have higher and positive BKAPI values. A larger percentage of the respondents in the *potential GM banana consumer* segment grow and buy bananas compared to those in the second segment, suggesting that a larger proportion of members in the consumer segment are banana-insecure. This may also imply that producer households that are not self-sufficient, as well as some net buyers, are more willing to try this new technology. For the *GM banana opponent* segment, on the other hand, food-environment and health safety are pressing issues, as evidenced by the positive values for these indices.

In terms of household characteristics, households in the *potential GM banana consumer* segment are larger than those in segment two. This implies that potential consumers may need a technology that provides higher yields to feed their larger-sized households. Banana decision-makers in this segment are also younger, and hence are more willing to adopt new technologies (such as GM crops). These findings are consistent with those from some other studies. For example, using CE data and the LCM approach, Hu et al. (2004) found that in Canada, the *value-seeking consumers*, who tended to be younger individuals from households with more children, were in favor of the presence of GM ingredients in bread and were interested in reasonably priced sources of healthy foods. Policies that restrict cost-reducing technologies such as GM technology would therefore adversely affect this category. Similarly, Li et al. (2002) and Lin et al. (2006) found that younger Chinese consumers were more willing to purchase GM rice. Furthermore, our results reveal that a significantly smaller percentage of respondents in the *potential GM banana consumer* segment have post-secondary education (i.e., college or university education) compared to those in the *potential GM banana opponent* segment. This implies that better-educated consumers are less likely to try GM biotechnology compared to less-educated consumers. This is similar to the findings of Krishna and Qaim (2008), who reported that better education reduced the acceptance of GM vegetables in India. Finally, a smaller proportion of households in the *potential GM banana consumer* segment have at least one household member working off-farm, and they have a lower average monthly income compared to those in the second segment. Consistent with the findings of other studies (e.g., McCluskey et al. 2003; Lin et al. 2006), our results suggest that wealthier people who have non-agricultural incomes are more likely to not to want GM food. These people are likely to demand larger discounts to consume GM bananas.

Consumer Valuation of Banana Bunch Attributes

The marginal value of each banana bunch attribute represents the consumer's willingness to pay a premium (positive WTP values) or discount (negative WTP values, i.e., willingness to accept (WTA) a discount) for a given attribute. The marginal value can be derived from the parameter estimates shown in Table 5 by using $W = -\dfrac{\beta_k}{\beta_y}$, where β_y is the marginal utility of income (i.e., the coefficient of the monetary attribute; in this study, it is the banana bunch price) and β_k is the coefficient of the banana bunch attributes (i.e., size, type of biotechnology, or benefit).

As shown in Table 7, marginal value figures were estimated for both segments. The numerical results represent the percentage change in the price consumers were willing to pay as a premium (or willing to accept as a discount if negative) for each banana bunch attribute. In other words, the implicit percentage price changes reflect each consumer's WTP for a distinct change in the attribute's level (e.g., to increase banana bunch size from small (the base level) to medium or large). The WTP increases with improvements in the attributes, as indicated in Table 7.

Table 7. Segment specific valuation of banana bunch attributes: Percentage change in price

Banana attribute	Segment 1 *Potential GM banana consumers* (N=285)	Segment 2 *Potential GM banana opponents* (N=176)	Weighted (N=421)
Bunch size: medium**	31.1 (27.5, 35.1)	37.7 (25.1, 57.6)	33.8(26.5,44.5)
Bunch size: large ***	43.1 (38.7, 48.2)	56.1 (39.7, 81.9)	48.6(39.1, 62.3)
Benefit: medium ***	11.2 (8.5, 14.9)	-20.9 (-24.1, -15.9)	-2.3(-5.2, 1.5)
Benefit: large***	18.1 (14.9, 21.7)	-75.3 (-82.1, -70.9)	-21.1(21.9, 21.1)
GM biotechnology***	42.5 (36.6, 49.3)	-62.4 (-81.7, -56.8)	-1.5(-2.6, -1.3)

Note. The numbers shown in parentheses are the 95% confidence intervals. Consumers' valuations of banana attributes were calculated with the Delta method of the Wald procedure contained within the LIMDEP 8.0 NLOGIT 3.0 program (William H. Greene, Economic Software, Inc.). Numbers represent the percentage change in total price per banana bunch.
* Significant at the 10% level.
** Significant at the 5% level.
*** Significant at the 1% level.

We see variation in the ranking of banana bunch attributes and their impact on consumer utility (as represented by WTP values) between the two segments. These results highlight the importance of investigating the heterogeneity of preferences across consumers. For members of the *potential GM banana consumer* segment, the marginal value of the bunch size (medium or large), benefit for producers (medium or large), and GM biotechnology attributes are positive and significant. This indicates that consumers in this segment are WTP price premiums for discrete changes in the levels of these attributes. *Potential GM banana consumers* derive the highest positive values from banana bunches that are large in size and arise from GM biotechnology. In contrast, *GM banana opponents* derive positive value only from the bunch size attribute; however, they are willing to pay a higher price premium for large bunches compared to their counterparts in segment one. Consumers in this segment are willing to accept a price discount for GM biotechnology, as well as for benefits for producers (medium or large).

5. CONCLUSIONS AND POLICY IMPLICATIONS

Two distinct segments of banana consumers are herein identified by LCM of Ugandan banana consumers. The first, labeled *potential GM banana consumers*, value large bunch size, followed by GM biotechnology, and large benefits for producers. These consumers are younger and have positive opinions regarding the benefits of GM food and crops. They have larger families and are less often employed off-farm, and hence have relatively lower monthly incomes. Most consumers in this segment are located in the rural areas of the Eastern region, where banana pests and diseases are prevalent. Consumers in this segment are more likely to be banana producers, and are more likely to complement their own production with market-bought banana bunches (i.e., they are less likely to be self-sufficient in banana consumption compared to the second segment). Based on marginal value estimates, they would be willing to pay larger premiums for GM bananas and to ensure that banana producers derive higher benefits. This finding suggests that GE bananas offering tangible benefits, such as pests and disease resistance and correspondingly higher yields, would likely be accepted by this segment, which represents about 58 percent of the sample. Consequently, the commercial release of such varieties would benefit the most vulnerable population segment, i.e., relatively poor rural households that grow and consume bananas. Thus, our present findings suggest that GM bananas could be a potentially pro-poor biotechnology in Uganda. This finding supports the work of Edmeades and Smale (2006), who concluded that purchasers of GM banana planting materials in Uganda are likely to be the poorer, subsistence-oriented households in regions greatly affected by biotic pressures.

In contrast, our analysis identifies ~42 percent of sampled consumers as *potential GM banana opponents,* who derive significant disutility from GM varieties and the associated producer benefits. Members of this segment are, however, willing to accept a discount for both GM bananas and their benefits to producers. Consumers in this segment are older and better off, they reside mainly in urban areas of the Southwestern and Central regions, and they largely associate GM banana with risks to food safety, the environment, and human health. This finding suggests that if *potential GM banana opponents* are offered much larger discounts, then a GM banana could successfully enter this segment of the Uganda banana market. This also implies that any decision made by regulators (policy-makers) to release a GM banana variety could impose greater negative impacts on this segment of the population, potentially inducing this segment of consumers to campaign against the introduction of GM food. Policy-makers should be aware of this possibility. Interestingly, stressing the benefits that the technology may provide to farmers is more likely to increase the opposition towards GM bananas among this consumer segment (see below for more detail on this).

The difference between the two segments supports Paarlberg's (2008) argument that the negative attitudes of urban elites in African countries can be explained by their views on GM food being closer to the European viewpoint versus that of the rural people in their own country. Our results suggest that this not only applies to urban elites, but to the urban population in general.

According to the welfare estimates reported herein, both the total WTP among those who gain from the introduction of the GM technology (segment one) and the total WTA for those who lose as a result of the introduction of this technology (segment two) are significant and large (Table 7). Further research is required to investigate these welfare impacts and to determine whether or not the gainers (the majority of whom are rural consumers) can potentially compensate the losers (urban consumers) if a GM banana is introduced in Uganda. Overall, these findings highlight the necessity to examine who gains and who loses from the introduction of a GM banana when devising strategies and policies for its dissemination and marketing.

Our results regarding the two segments' valuations of the "benefits for producers" attribute are comparable to the findings of Bergmann et al. (2006) and Bergmann et al. (2008), who reported that rural respondents in Scotland were willing to pay a premium for rural employment creation, whereas members of the urban population were indifferent. In our sample, most banana consumers living in rural areas are also banana producers, providing a logical explanation for the positivity of the "benefits for producers" attribute in this segment. The benefit attribute measures the benefits these households would derive as producers (i.e., the values reflect the banana consumers' indirect benefits, which they derive as producers). Rural consumers are willing to pay a higher premium for producer benefits compared to their urban counterparts, suggesting a significant difference between urban and rural consumers' preferences regarding producer benefits. Similar to the case of developed countries, where many consumers are not willing to pay a premium for a GM technology that gives higher returns for farmers (Loureiro and Bugbee 2005), for the developing country of Uganda, our results suggest that urban consumers are more concerned about the potential risks of the technology compared to the social benefits it may generate for farmers.

Overall, our results suggest that the potential for benefits to producers alone would not be enough to counteract the risk perception among urban consumers. These findings should be taken into consideration when designing appropriate biosafety regulatory frameworks and efficient and effective marketing and extension strategies for introducing GM banana varieties in Uganda. Although this paper sheds some light on the differences between urban and rural consumers' preferences, further research will be required to give us a detailed understanding of why urban consumers derive disutility from GM bananas and their associated benefits for producers.

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