# On the introduction of genetically modified bananas in Uganda: Social benefits, costs, and consumer preferences

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# Contents

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# Abstract

Agriculture is the mainstay for the great majority of rural people in most African countries and is essential for poverty reduction and food security. The role of agriculture towards poverty reduction, however, has not been realized in Africa, despite advances in development of technologies such as improved varieties suitable to local conditions and resistant to pests, diseases and droughts stresses. Plant breeding using modern biotechnology and genetic modification in particular has the potential of speeding-up crop improvement. However, the central issue in agricultural biotechnology particularly in Africa is to achieve a functional biosafety system to ensure that a country has the capacity to assess risks that may be associated with modern biotechnology. Several countries have designed and implemented policies to address the safety concerns of consumers and producers, including environment and food safety. One of the requirements, as proposed in Article 2 of the Cartagena Protocol, is the inclusion of socioeconomic considerations in the biosafety assessment process. Many developing countries, including Uganda, have not determined whether and how to include socioeconomic considerations. Specifically, at what stage of the regulatory process should they be included, the involved scope, as well as the nature of the decision-making process within the biosafety regulations. The aim of my thesis is to examine potential social welfare impacts of introducing a GM banana in order to illustrate the relevance of socioeconomic analyses for supporting biotechnology decision-making and in particular the importance of consumer perceptions but also for contributing to the development and implementation of biosafety regulations. I present a general approach using GM banana as an example, while assuming the GM banana has passed standard food and biosafety safety assessments, i.e. can be considered to be safe. I explore the benefit-cost trade-offs of its introduction and the farmers' and consumers' willingness to pay for the technology and the end product. In the study I present a framework for considering concerns about genetically modified crops within a socioeconomic analysis of GM crops, using real options and choice experiment approaches. The approaches relate the economic benefits to consumers' concerns. The results show that the introduction of GM bananas would be desirable for the Ugandan society as a whole, mainly benefit poor rural households and would merit policy support. Nevertheless, if such a GM banana is introduced its introduction may result in strong opposition from the opponent segment of the population, which is composed of mainly urban consumers with an on average higher education and income. Interestingly and in contradiction to common wisdom only providing additional information about the technology and its safety will not result in higher acceptance. Based on this case study biosafety regulators would need to consider these socioeconomic effects before a decision to introduce a GM banana is made. However, the decision to consider socioeconomic impacts for other GM crops elsewhere depends on the crop and the country. The research methodology in this thesis provides the basis for assessing other GM crops as well.

# Chapter 1

# General Introduction

## 1.1 Background and problem statement

Africa's agriculture is seen as having a huge potential for growth due to its natural resource base, including land and water. Agriculture is the mainstay for the great majority of rural people in most African countries and is essential for poverty reduction and food security (FAO 2009). The role of agriculture towards poverty reduction, however, has not been realized (World Development Report 2008, World Bank 2008), despite advances in development of technologies such as improved varieties suitable to local conditions and are resistant to pests, diseases, and droughts stresses. The main limitation has been the failure for the resource-poor smallholder farmers to access new technologies and crop management techniques aimed at improving crop productivity and hence increasing incomes (FAO 2009; Paarlberg 2008).

Plant breeding using modern biotechnology [1], in particular genetic modification (genetic engineering), has the potential of accelerating crop improvement, which may increase yields and/or decrease yield losses. This is because it is faster and more accurate to transfer desirable traits into crops, especially in cases where conventional breeding may be difficult. Genetic modification for biotic stress and herbicide resistance has been successful, and the adoption rate and the associated benefits resulting from adopting genetically modified (GM) crops with such traits has increased in developing countries (Brookes and Barfoot 2009; Qaim 2009; James 2008). The planting of GM crops over the past 10 years increased substantially. Approximately 125 million hectares were planted with GM crops in 2008, of which 43 percent were planted in developing countries (James, 2008). China, India, Argentina, Brazil and South Africa contributed approximately 40 percent of the global total or 46 million hectares (James 2008). In Africa only South Africa, Egypt and Burkina Faso have commercialized GM crops, while Kenya, Uganda and Nigeria have GM crops under confined field trials (Karembu, Nguthi, and Ismail 2009). Ghana, Mozambique and Tanzania also have ongoing GM crops research activities, particularly on food staples (Karembu, Nguthi, and Ismail 2009). The GM crops include industrial crops (e.g. cotton) and staple food crops (e.g. banana, cassava, maize, sweet potatoes and sorghum). With these developments in GM crops

[1] The terms biotechnology and technology are used interchangeably in the whole thesis.

research, some experts predict that by 2050 GM crops will be cheaper, readily available and with the potential to increase yields and yield stability for staple food crops (FAO 2009).

The GM banana is the pioneer staple food crop developed through modern biotechnology in Uganda. There are many staple crops in Uganda, but banana pioneered modern biotechnology research due to a couple of reasons: first, the modern biotechnology innovations target economically important biotic constraints that cannot be easily addressed through conventional breeding or methods of control as the crop is sterile (de Vries and Toenniessen 2001). Second, banana poses little risk of jeopardizing trade through exports to countries that do not accept transgenic products such as the EU (Nielsen, Thierfelder and Robinson 2001). This is because the East African highland cooking bananas are mostly produced and consumed locally, with little regional trade and negligible exports. Third, GM bananas have been demonstrated to make a difference in smallholder farmer's welfare as a source for food and/or income (Smale and Tushemereirwe 2007).

In spite of their potential toward food security in developing countries, the adoption of GM crops is still affected by public opinions including anti-GM lobby groups (Qaim 2009). The major public concerns are the potential negative effects on the environment and human health (FAO 2004). Environmental risks such as gene flow, evolution of resistance in the targeted pest population or impacts on non-target organisms as well as food safety are always debated (Qaim 2009; Smale et al. 2006). Smale et al. (2006), for example, discuss the potential risks of GM bananas, and the authors highlight the existence of limited scientific evidence on the effects of GM bananas on human health and non-target species. Another key concern has been the potential loss of genetic diversity with the introduction of GM bananas (FAO 2001). These concerns may raise questions about the safety of GM banana varieties. In this context risk assessment is very vital before a decision to release GM banana is made. Nevertheless, even if a GM banana passes the health and biosafety assessment, as Paarlberg (2008) argues, consumer wariness may continue to play a significant role in the introduction of GM bananas in Uganda, even if they are proven safe for human health and the environment. The risk assessment may not meet the consumers' needs for food and biosafety.

Developing countries have developed biosafety and biotechnology frameworks, laws, and regulations as a response to the implementation of the Cartagena Protocol on Biosafety. The objective of the Cartagena Protocol, a supplement to the Convention on Biological

Diversity, is to contribute to ensuring adequate level of protection related to the transboundary movements including the safe transfer, handling, and use of living modified organisms, with a special focus on those that may have an adverse effect on biodiversity. Although the main focus of the Cartagena Protocol is on environmental issues, the focus of biosafety assessments has been expanded to account for potential risks to human and animal health and other considerations such as socioeconomic issues. This international agreement aims at ensuring that countries have the capacity to assess risks that may be associated with modern biotechnology.[2]

Several countries have designed and implemented policies to address the safety concerns of consumers and producers (Karembu, Nguthi, and Ismail 2009; Beckmann, Soregaroli, and Wesseler 2006a; 2006b). Such policies include assessment, management, and communication of the biosafety profiles of GM organisms (Falck-Zepeda 2006). Because of its international obligations and the need to guarantee a socially accepted level of safety to its citizens, Uganda has taken significant steps to ensure the safety of modern biotechnology applications. A summary showing the sequential events taking place in the governance of modern biotechnology is presented in appendix A1.1. In April 2008, the Ugandan government approved the National Biotechnology and Biosafety Policy, which provides a guiding framework for safe use or application of modern biotechnology. Uganda National Council of Science and Technology (UNCST) is the institution responsible for the implementation of the biosafety protocol and the protocol's designated competent authority. UNCST established the National Biosafety Committee (NBC), a technical evaluation arm, in 1996. NBC is responsible for reviewing applications and implementing general biosafety guidelines and regulations (Wafula and Clark 2005; GOU 2004). GM crops will need to receive the regulatory approval of the country's NBC before being approved for release into the environment for commercialization. However, as Jaffe (2006) notes, while existing drafts of Uganda's biotechnology and biosafety policy stress the importance of the socioeconomic implications of the technology for biosafety regulation, there is a lack of mechanisms to

[2] 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". In this definition, products that arise from both traditional and modern biotechnology are included. Traditional biotechnology may include products of tissue culture, micro-propagation or those used to eliminate diseases, while modern biotechnology considers use of DNA diagnostic probes, recombinant DNA, functional and structural genomics and other methods for genetic modification. Yet, only products of genetic modifications, termed as Living Modified Organisms, are subject to biosafety assessments under the Cartagena Protocol on Biosafety (Falck-Zepeda 2009).

ensure precision in identifying the socioeconomic aspects and how they could be integrated in decision-making processes.

The biosafety regulatory process, however, has several economic consequences as biosafety regulations are not costless endeavors. Kalaitzandonakes, Alston, and Bradford (2007) calculate the compliance costs for regulatory approval of herbicide-tolerant and insect-resistant maize to be in the order of about US$7 to 50 million. They note that the approval costs for similar types of GM crops will be alike. In addition, biosafety-testing requirements can consume significant amounts of time—from a few months to several years. A delay in the approval of a new variety forestalls access to the potential benefits generated by farmer adoption of the technology, and one can expect such costs to be substantially higher than the regulatory compliance costs (Beyer, Norton, and Falck-Zepeda 2008). However, regulatory processes create additional information about the technology and can help to improve the selection and regulation of appropriate technologies.

Article 26.1 of the Cartagena Protocol gives countries the choice of whether to include socioeconomic considerations in the biosafety assessment process consistent with other international treaties although limited to the context of biodiversity (Jaffe 2006). Article 26.1's "may take into account" clause has been applied strictly in some countries, such as Argentina, where the socioeconomic consideration is mandatory but limited to trade impacts (Falck-Zepeda 2009).

Many developing countries, including Uganda, have not determined whether and how to include socioeconomic considerations. Specifically, at what stage of the regulatory process should they be included, the involved scope, as well as the nature of the decision-making process within the biosafety regulations. Besides, countries need to decide what the decision-making rules are that will incorporate outcomes from different processes—i.e., risk assessment vs. socioeconomics vs. ethical issues. In fact, some biosafety experts (and some countries) have resisted including such considerations in the biosafety decision-making process. In their view, such issues may cloud the process and distract regulators from the scientific/technical issues related directly to biosafety (e.g. Paarlberg 2008). Furthermore, the inclusion of socioeconomic considerations for biosafety regulatory approval at the laboratory/greenhouse or confined field trial stages contributes very little to the decision-making process, as the material at the end of the confined or contained trial, will not enter the food chain and thus will not be commercialized until it is given regulatory approval further along the process.

The analysis of socioeconomic implications relevant to GM crops—e.g. GM staples—is lacking in Uganda as the country is still developing its official policies towards biotechnology and biosafety. If a country decides to include socioeconomic issues into its decision-making process, it is important to implement effective strategies for socioeconomic impact assessments in order to achieve a functional biosafety system as discussed by Jaffe (2005), which are also in line with other international agreements.

In this thesis a genetically modified cooking banana, referred to as GM banana, is presented as a case study to explore the cost-benefit trade-offs of its introduction and the farmers' and consumers' willingness to pay for the technology and the end product. I explore the socioeconomic impacts of introducing and adopting a GM banana assuming it is proven safe for human health and the environment. Consumer knowledge, attitude and perception towards modern biotechnology may continue to play a fundamental role in the success of GM bananas even if proven safe. Understanding those issues beforehand can help to improve the government policies toward GM crops, which in turn could increase consumers' trust and confidence in GM products.

The next section of this introductory chapter briefly describes the relevance of GM bananas for the Ugandan resource-poor smallholder farmers. The main objective and the guiding research questions are outlined in section 1.3. Section 1.4 briefly describes the methodological approaches and data used. The overall contributions of the study are highlighted in section 1.5. The plan of the thesis is set out in the final section of this chapter.

## 1.2 The relevance of a GM banana for Uganda

Banana is one of the most important crops in Uganda with approximately seven million people, or 26 percent of the population, depending on the plant as a source of food and income. Bananas are estimated to occupy 1.5 million hectares of the total arable land, or 38 percent of the cultivated land, in the country (Rubaihayo and Gold 1993; Rubaihayo 1991). The plant is grown primarily as a subsistence crop in rural areas, although consumption is not limited to rural areas as approximately 65 percent of urban consumers in Uganda have a meal of the cooking variety of banana at least once a day. In general, Ugandans have the highest per capita consumption of cooking banana in the world (Clarke 2003).

Most of the banana varieties grown in Uganda are endemic to the East African highlands—a region recognized as a secondary center of banana diversity (Smale and Tushemereirwe 2007; Swennen and Vuylsteke 1988; and Stover and Simmonds 1987). The endemic banana varieties (AAA–EA genomic group) consist of two use-determined types: cooking bananas (matooke) and beer bananas (mbidde). Karamura (1998) recognized 238 names of East African highland banana varieties in Uganda, with 84 clones grouped into five clone sets. The non-endemic clones include dessert bananas (varieties that are consumed raw), some beer bananas (varieties suitable for beer and juice making), and roasting bananas (or plantains).

However, increase in production has not been kept with population growth. Banana yields in Uganda are severely reduced by several pests and diseases. Among the pests that cause the most yield damage are weevils (*Cosmopolites sordidus*) and nematodes (*Radopholus similis,Pratylenchus goodeyi, and Helicotylenchus multicinctus*). The diseases that contribute to the worst yield losses in Uganda are the soil-borne fungal Panama disease, or *Fusarium* wilt (*Fusarium oxysporum*), bacterial wilts including the banana *Xanthomonus* wilt (*Xanthomonus campestris* pv. *musacearum*), and the air-borne fungal black leaf spot disease or “black Sigatoka” (*Mycosphaerella fijiensis* Morelet) (Tushemereirwe et al. 2003; Gold et al.2001; Gold 2000; 1998; Gold et al. 1998). Currently, most banana-producing households in Uganda grow local cultivars of the East African highland cooking bananas which are susceptible to such pests and diseases. Farmers reproduce banana varieties through vegetative propagation, and replace a diseased banana by replanting suckers of the same cultivar obtained from their respective plantations or from other farmers within or outside the village. This practice greatly contributes to the spread of pests and diseases and is reason why farmers fail to control pests and diseases using only the current best agronomic practices known to them.

To address these constraints, the country has invested significant resources in research and development and other publicly funded programs, pursuing approaches over both the short and long term. Uganda formally initiated its short-term approach in the early 1990s; it includes the collection of both local and foreign germplasms for the evaluation and selection of cultivars tolerant to the productivity constraints. Resistance to a limited set of pests and diseases (e.g. black Sigatoka) was identified in hybrid banana varieties. Though characterized by bigger bunches, the hybrid varieties are not widely grown in Uganda (Smale and Tushemereirwe 2007; Nowakunda 2001). Producers and consumers prefer the East African highland cooking bananas, but these are also highly susceptible to black Sigatoka (Nowakunda 2001; Nowakunda et al. 2000) and bacterial wilts (Tushemereirwe et al. 2003). This disease susceptibility prompted the national researchers to adopt a long-term breeding strategy that includes the generation of new genotypes and use of other new approaches to introduce pest and disease resistance.

The long-term approach, launched in 1995, includes breeding for resistance to the productivity constraints using conventional (cross) breeding methods and genetic engineering. The most preferred East African highland cooking bananas, however, are difficult to improve through cross-breeding because they are all triploids. Plants with three genomes, rather than two or four, produce no pollen and are sterile. Genetic engineering projects in Uganda target the most popular and infertile cultivars that cannot be improved through conventional breeding (Kikulwe et al. 2007), which involves the insertion of resistance traits into selected banana background planting material. Unlike crossbreeding, genetic engineering strategies improve agronomic traits (e.g. disease and pest resistance) by inserting genes into potential host varieties without altering other production and product attributes (e.g. cooking quality).

The National Agricultural Research Organization (NARO) has successfully adopted modern biotechnology approaches to improve the banana crop. Kiggundu et al. (2008) report that various projects have been realized such as developing transformation systems for the East African highland banana, and the use of recombinant DNA technology to genetically improve the crop for resistance against black Sigatoka disease, bacterial wilt, nematodes and weevils. Other developments include virus diagnostics, architectural trait improvement such as early maturity and delayed ripening, as well as bio-fortification. All these technologies are at various stages in the genetically modified product development pipeline. The most advanced technology is a GM banana, resistant to black Sigatoka, which is undergoing biosafety assessment in confined field trials (CFT) at the National Agricultural Research Laboratories Institute, Kawanda. It is the first confined field trial for transgenic bananas in Africa.

## 1.3 Study objective and research questions

The general objective of this study is to examine potential social welfare impacts of adopting a GM banana in order to illustrate the relevance of socioeconomic analyses for supporting biotechnology decision-making and in particular the importance of consumer perceptions but also for contributing to the development and implementation of biosafety regulations. To achieve this goal five research questions are addressed:

1. What are the expected social incremental benefits and costs under effects of irreversibility, flexibility and uncertainty of introducing genetically modified bananas in Uganda?
2. What are consumers' knowledge, attitudes, and perceptions toward introducing genetically modified bananas in Uganda, how do they differ between rural and urban households, and do consumers know, and have trust in, the institutions responsible for regulating GM crops in Uganda?
3. How does preference heterogeneity influences choice of banana bunch attributes across individual households, and what are the differences between the consumer preferences for urban and rural households towards banana bunch attributes?
4. How much are consumers' willing to pay for the values accruing from GM bananas given a social benefit, and how does it compare across different population consumer segments?
5. What are the impacts of introducing GM bananas on food security in Uganda, and what implications does this have for biosafety regulations in general?

It is important to note that the GM banana will be one of the first public sector releases (if it is proven safe) in a staple food crop context of a developing country.

## 1.4 Research approach and data

The study employs two methodological approaches, real options and choice experiment. The real option approach is a cost-benefit analysis (CBA) under irreversibility, uncertainty, and flexibility (Dixit and Pindyck 1994). That is, the initial investment costs of introducing GM bananas are somewhat sunk (irreversible) and the decision to invest depends on future profits of the investment (uncertainty), which can be postponed to get more information about the future (flexibility). The real option approach considers the irreversible effects to see how the stream of incremental benefits will be affected in a longer planning horizon— continuous state, continuous time. All these conditions are not taken care of under the traditional CBA, which assumes investments to be reversible. A choice experiment approach is a stated preference method normally employed to provide four pieces of information about a non-market good: (1) which attributes are significant determinants of the product value; (2) the relative rank of attributes among relevant populations; (3) the value of changing more than one attribute at once; and (4) the total economic value of the good (Bateman et al. 2003). A choice experiment is a highly structured method of data generation that relies on carefully designed tasks or experiments to reveal the factors that influence choice, but requires large sample sizes. The good is defined in terms of its attributes and the levels these attributes would take under different management scenarios. One of the attributes is the price, which enables estimation of the welfare measure, or value. Experimental design theory is used to construct profiles of such a good in terms of its attributes and attribute levels. Often, two or three alternative profiles are assembled in choice sets and presented to respondents, who are asked to state their preferred profile in each choice set (Louviere et al. 2000; Bennett and Blamey 2001; Bateman et al. 2003). This non-market valuation method was used to determine the willingness to pay for a GM banana. The conceptual framework, therefore integrates economic and consumer perspectives.

Different econometrical models were used to answer the five research questions. For question one, I calculated the incremental benefits for producers, which may be foregone if a GM banana is not released. A real option model was employed to calculate the maximum incremental social tolerable irreversible costs (MISTICs) within a cost-benefit analysis as a first step toward a socioeconomic assessment of introducing a GM banana in Uganda.

Question two aims at exploring the consumer knowledge, attitudes, and perceptions (KAPs) and institutional awareness in relation to the introduction of a GM banana. Based on the objective of this study, a household survey was designed in order to capture data on consumers' KAPs toward GM crops (foods), and awareness and trust among both urban and rural households. Factor analysis that collapses the number of variables, classifying them according to their correlation and structure was employed. Factors influencing GM banana purchase decision as well as consumers' awareness of and trust in institutions are considered.

Question three aims at analyzing differences in preferences towards banana bunch attributes among urban and rural communities. I used various banana attributes including both conventional banana attributes such as bunch size and price, and more unconventional ones such as whether or not the banana is of GM variety and whether or not consumers value production benefits that accrue to the producers to determine consumers' preferences. I used random parameter logit models including direct interactions of consumer-specific characteristics with banana bunch attributes in the utility function to investigate consumers' valuation of the banana attributes, taking into consideration preference heterogeneity resulting from locational and household income groups.

Question four aims at investigating further the heterogeneity in consumers' preferences for banana attributes, and their characteristics at segment level rather than individual level. In addition, the KAP variables estimated in question two are integrated with consumer-specific socioeconomic characteristics to explain the source of preference heterogeneity. I used a latent class model to explicitly capture and account for heterogeneity among consumer preferences given a tangible economic benefit of the GM bananas. The latent class approach enables simultaneous identification of the characteristics that differentiate banana-consuming households and the values that these consumers derive from banana bunch attributes. I identified the characteristics such as income, location, education and KAPs of consumers who are more or less likely to accept GM bananas.

Question five addresses the policy implications regarding biosafety regulation and GM crops introduction in Uganda. First, I used a compensation surplus welfare measure to determine the total WTP for various GM banana improvement scenarios. The calculations are based on the best-fit model estimated for question three and four. Second, I calculated the MISTICs per banana bunch for different risk-free and risk-adjusted discount rates of return based on estimates under question one. Finally, I compared the MISTICs per bunch associated with the immediate introduction of a GM banana with the total WTP values for the GM banana attributes for different scenarios.

The study uses both time series and survey data. Time series data on cooking banana production, from 1980 to 2004, was obtained from the Uganda Bureau of Statistics (UBOS) and the Food and Agriculture Organization databases. Survey data was generated from a survey conducted in three administrative regions, Eastern Region, Central Region, and

Southwestern Region, comprising three distinct agro-ecological zones where cooking bananas are produced and consumed. The survey material is included in the appendices to this thesis. The Eastern Region and Central Region are located in the lowlands, where banana production is severely hit by pests and diseases, yet the demand for banana is high. The Central Region, in addition, is the major trading place for banana bunches (Bagamba 2007). The Southwestern Region is the main banana-producing region located in the highlands, characterized by low incidences of pests and diseases. The consumer characteristics, choice experiment and consumers' knowledge, attitudes and perceptions data were collected from 421 banana consuming households in both rural and urban areas of the three regions.

## 1.5 Contribution of this research

The novelty of this study is in a combination of different models analyzing production outcomes and consumer preferences. Specifically, this thesis makes new contributions to the literature on consumers' preferences for products of agricultural biotechnological innovations in the following ways:

First, in a recent review of literature Smale et al. (2009) highlight that in developing countries there is a general lack of empirical studies integrating consumers' preferences with farmers' adoption of GM crops. That is, linking the propensity to purchase and propensity to adopt in one study. Yet in such countries the market chain length is considerably short. My study links both sides of the market for a major food staple by incorporating farmers as consumers with sole consumers in order to examine the heterogeneity in their preferences for GM bananas. Farmers have heterogeneous preferences regarding crop choices that depend on economic and socioeconomic factors and are well documented in the literature. Those preferences are likely to affect the willingness to pay (WTP) as well as the likelihood of adoption. The WTP of sole consumers as well can be expected to depend on differences in income, education, age, and other household characteristics. On the one hand, sole consumers may assign higher utility values to high quality, and more nutritious bananas. On the other, they may be more concerned about the future health risks of GM crops (food), which would negatively influence their WTP. These possibilities were explored in this study.

Second, the use of choice experiment approach in this study contributes to the scanty literature on understanding consumer preferences for biotech food in Africa, in particular Sub-

Saharan Africa. Employing choice experiments in this study complements and extends the dimensions of previous studies (e.g. Knight et al. 2007; Loureiro and Bugbee 2005; Onyango and Govindasamy 2005; Li et al. 2002) on consumers' willingness to pay for GM food. My study incorporates the foregone economic benefits to farmers of a delay in release of GM bananas.

Third, a few previous applied economics *ex ante* studies have investigated the determinants of the potential demand/supply for improved traits of banana varieties (e.g. GM bananas) in Uganda (Edmeades 2007; Edmeades and Smale 2006). These studies have been based on the theoretic framework of the household, a revealed preference method, using data collected from only banana-producing households and without considering consumers' knowledge, attitudes and perceptions towards biosafety risks of GM organisms. Assessing consumer preferences in my study contribute to the knowledge of understanding the extent of concerns (e.g. consumer attitudes toward biosafety risk) about GM organisms in a heterogeneous banana industry.

Finally, comparing the MISTICs, the social incremental reversible benefits (SIRBs), and the WTP provides important information for the socioeconomic impact assessment of genetically modified biotechnologies.

## 1.6 Plan of the thesis

The study is composed of seven chapters, including the general introductory chapter. Chapters 2 through 6 address the five research questions outlined in section 1.3, which were originally prepared as individual journal articles submitted (or to be submitted) for publication. Thus some overlaps in data descriptions are expected. This section presents the highlights therein each chapter.

Chapter 2 provides estimates for threshold values that indicate the maximum incremental social tolerable irreversible costs that an individual or society in general is willing to tolerate as compensation for the benefits of the GM technology. Additionally, the chapter estimates overall expected social incremental reversible benefits (SIRBs) for cultivating a GM banana in Uganda per year. The SIRBs can be an indicator of how much Uganda can pay to compensate for potential damages. Furthermore, the SIRBs provide a clue about the maximum costs farmers would endure in order to comply with biosafety regulations, including the cost of implementing coexistence policies.

Chapter 3 provides consumers' knowledge, attitudes and perceptions that may represent the behavioral and attitudinal concerns towards the introduction of GM banana in Uganda. In addition, the chapter gives a detailed description of the sample survey design.

Chapter 4 presents the theoretical framework of the choice experiment method, the conditional logit and random parameter logit models and explains the choice experiment design and its administration. Consumers' valuation of the banana attributes, taking into consideration preference heterogeneity resulting from locational and household level characteristics at individual household level are investigated.

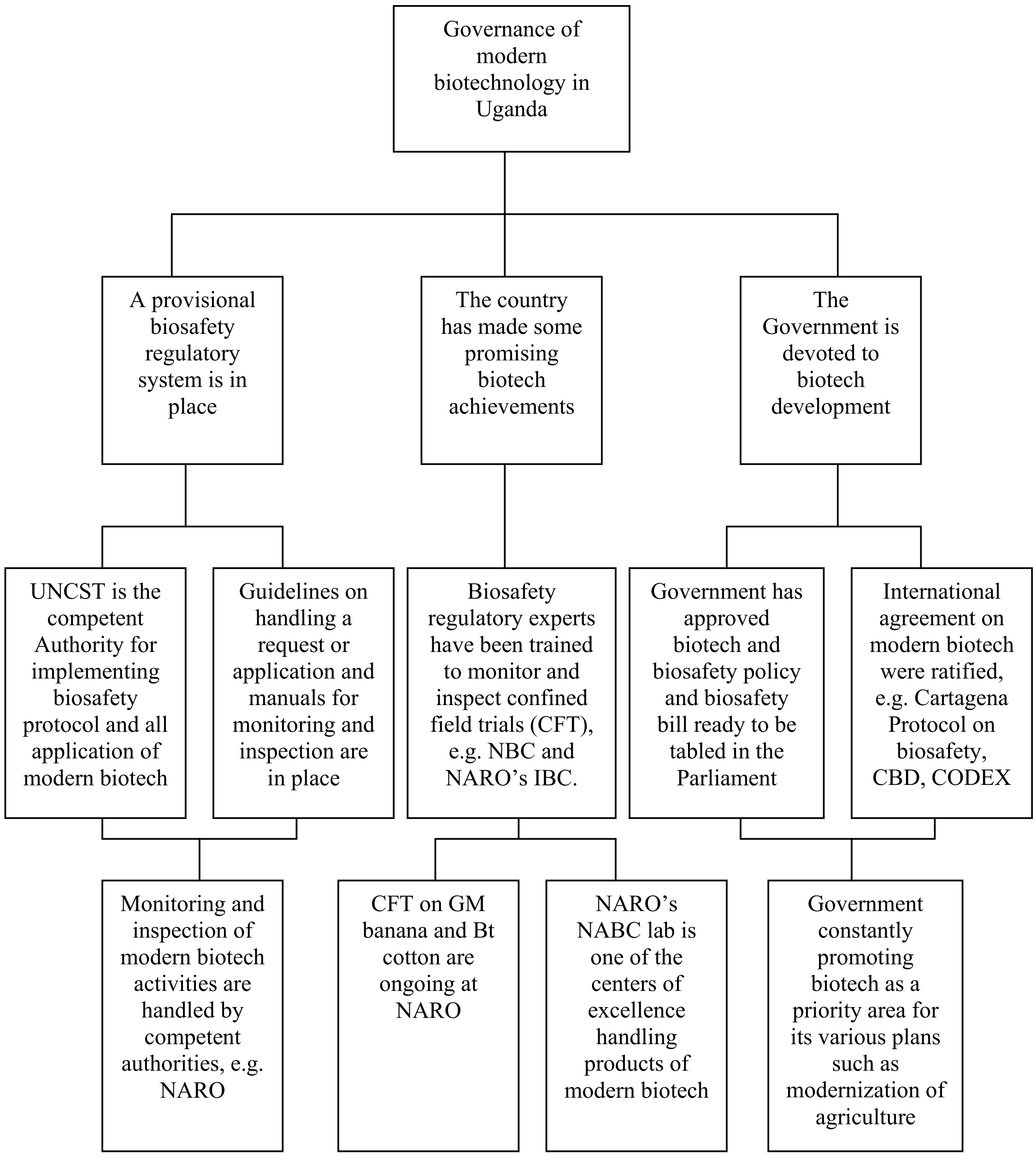
While it makes sense to do a different analysis, chapter 5 discusses the theoretical framework of the choice experiment method and the latent class model, which enables for simultaneous determination of different consumer segments within the population—and their preferences for different banana bunch attributes. The characteristics of consumers who are more or less likely to accept GM bananas at segment level are identified.

Chapter 6 describes the application of compensating surplus and willingness to pay. Total WTP values are calculated and compared with the calculated MISTICs. The chapter presents and discusses the welfare estimates and impacts towards introducing GM bananas in Uganda.

Chapter 7, finally, highlights the main findings of the study, and presents the main conclusions that can be drawn from the preceding chapters. The chapter also draws and discusses the major policy implications, limitations of the study, and suggestions for future research.

# Appendix

**Appendix A1.1. The sequential events taking place in governance of modern biotechnology in Uganda.**




Source: author's elaboration based on Navarro (2008) framework.

# Chapter 2

# Incremental Benefits of Genetically Modified Bananas in Uganda[♦]

[♦] A version of this chapter was published as Kikulwe, E., J. Wesseler, and J. Falck-Zepeda. 2008. Introducing a Genetically Modified Banana in Uganda: Social Benefits, Costs, and Consumer Perceptions. Discussion Paper no. 767. Washington, D.C: International Food Policy Research Institute. This chapter was also presented at the Mansholt Graduate School of Social Science PhD day (2008). The latest version has been submitted to *International Journal of Biotechnology*.

## Abstract

Banana is one of the staple crops for rural and urban households in Uganda. The government of Uganda initiated a genetic engineering breeding program addressing the most important local banana diseases. The aim is to produce a Genetically Modified (GM) banana for subsistence oriented farmers in areas greatly affected by biotic constraints. Prior to the release of GM banana, new varieties have to undergo a biosafety assessment, as mandated by the current biosafety regulations in Uganda. The analysis of biosafety issues relevant to the GM banana and the socioeconomic implications, as well as the decision-making process that will be followed has not been specified sufficiently as Uganda is still developing its official policies towards biotechnology and biosafety. This study proposes a framework that considers societal concerns of genetically engineered crops as well as societal benefits of improved banana varieties. Firstly, we calculate the reversible and irreversible benefits and costs of introducing GM banana. We apply a real option approach to calculate under different scenarios the maximum incremental social tolerable irreversible costs (MISTICs) that would justify an immediate introduction of GM banana. Secondly, we discuss the implications of our analysis for the biosafety regulations in Uganda. Results indicate the average annual MISTICs per household are approximately US$ 38. This implies that only if the average household is willing to give up more than US$ 38 annually for not having GM bananas introduced should an immediate release be postponed. Results also imply that, taking longer than necessary to approve a GMO may presumably result in failure to access the expected benefits from GM banana ranging between US$ 179 to 365 million per year.


**Key words:** GM banana, real option, socioeconomic aspects, MISTICs, biosafety, Uganda

## 2.1 Introduction

Ugandans have the highest per capita consumption of cooking banana in the world (Clarke 2003). However, banana production in Uganda is limited by several productivity constraints such as pests, diseases, soil depletion, and poor agronomic practices. To address those constraints, the country has invested significant resources in research and development and other publicly funded programs, pursuing approaches over both the short and long term. Uganda formally initiated its short-term approach in the early 1990s; it involves the collection of both local and foreign germ plasms for the evaluation and selection of cultivars tolerant to the productivity constraints. The long-term approach, launched in 1995, includes breeding for resistance to the productivity constraints using conventional breeding methods and genetic engineering. Genetic engineering projects in Uganda target the most popular and infertile cultivars that cannot be improved through conventional breeding. The main objective of genetic engineering in Uganda is to develop genetically modified (GM) banana cultivars that are resistant to local pests and diseases, have improved agronomic attributes, and are acceptable to consumers (Kikulwe et al. 2007).

However, GM bananas are currently a non-tradable good in Uganda, as they are still undergoing confined field trial assessments. In fact, the introduction of GM banana in Uganda is likely to generate a wide portfolio of concerns even if proven safe by scientists—as it has in other African countries. According to the Uganda National Council of Science and Technology (UNCST) (2006), for example, the main public concern is the safety of the technology for the environment and human health. Even if approved to be safe, the concerns about the GM crop compliance with biosafety regulations and the potential environmental and food safety risks can be important obstacles to public acceptance of biotechnology products in Africa (Paarlberg 2008). Therefore, without the consent of the society at large, GM banana may fail in the Ugandan market.

In this chapter we present a real option model that shows how concerns about environmental risks can be considered within a cost-benefit analysis as a first step toward a socioeconomic assessment of introducing a GM banana in Uganda. We estimate the economic welfare by considering the irreversible effects to see how the stream of incremental benefits will be affected under a longer planning horizon. This is the first study to show how much incremental benefits farmers (and consumers) would forego if a GM banana is not introduced in Uganda even though the crops has passed the biosafety assessments. In a thought experiment we show how much incremental benefits consumers would forego if a safe GM banana is not accepted in Uganda.

A few ex ante studies (Kalyebara, Wood, and Abodi 2007; Qaim 1999) have been conducted in the region to assess the economic benefits of biotechnology. Qaim (1999) assessed the welfare effects of adopting banana tissue culture planting materials in Kenya and Kalyebara, Wood, and Abodi (2007) simulated gross economic benefits for banana that could be generated by a set of technology options—including current cultural practices, conventional improvement and genetic transformation—if they are successfully developed and adopted in Uganda. In these studies, authors estimated the welfare effects using the economic surplus framework considering a finite time period (i.e., 20 years for Qaim and 30 years for Kalyebara, Wood, and Abodi). In both studies, uncertainties about the benefits and costs as well as irreversible environmental concerns were not modeled explicitly, yet consumers are often more concerned about the unknown irreversible effects in case of GM crops than the reversible benefits they may generate in Africa and elsewhere (Paarlberg, 2008).

Irreversibilities and uncertainties have been considered within the literature on introducing GM crops (e.g. Wesseler, Scatasta, and Nillesen 2007). Scatasta, Wesseler, and Demont (2006) introduced the term maximum incremental social tolerable irreversible costs (MISTICs) to identify the threshold value for consumer's willingness-to-pay for not having a GM crop being introduced; the use of the concept within the biosafety debate is new.

Thus, we make two contributions to the knowledge concerning the relevance of socioeconomic analyses of GM crops. First, we present a general approach for assessing ex-ante the economic benefits of introducing a GM banana in Uganda under uncertainty and irreversibility. Second, we discuss the main implications for biosafety regulations of GM crops in Uganda.

The chapter is structured as follows. The following section presents the MISTICs approach and explains its application for assessing the introduction of GM banana. Section 2.3 presents the data and its sources and section 2.4 reports and discusses the results. The final section draws conclusions and discusses implications for biosafety regulations of GM banana and GM crops in general in Uganda.

## 2.2 Toward considering the socioeconomic aspects of a GM banana

The economic net benefits of introducing a GM banana depend on the reversible and irreversible benefits and costs the technology will generate. Reversible benefits and costs can be defined as those benefits and costs that can be reversed after the planting of the crop and do not result in additional ex post (after stopping production) benefits and costs. An illustrative example is the purchase of inorganic fertilizer. If the producer finds that producing a GM banana crop is no longer worthwhile,—for instance, price has drastically reduced or consumers do not like the GM banana or as more information is availed, it is discovered that there are important negative effects of the crop and then its production is suddenly stopped by regulators—the purchased fertilizer can be used for other crops. Similarly, other variable costs can be considered as being reversible as well.

On the other hand, irreversible benefits and costs refer to those benefits and costs that will continue to occur even if GM bananas are no longer produced or those that cannot be fully reversed. Examples are sunk costs or chronic health damages from pesticide use. The reversible and irreversible benefits and costs can be further differentiated into private and non-private benefits and costs. This differentiation is useful for understanding the distribution of benefits and costs between, for example, farmers (private) and society at large (non-private) (see Wesseler 2009). The non-private costs include e.g. the effects on non-target species; for instance, the introduced genes in nematode-resistant GM banana may affect beneficial non-target nematodes. Others include effects on human health such as antibiotic resistance and allergies, evolution of pests and disease resistant to the inserted genes (e.g. Kendall et al. 1995) and loss of genetic diversity (FAO 2001). Certainly, a net reduction in the use of insecticides and nematicides on GM banana will have positive impacts on human health, the environment, and biodiversity, and those can be considered as being irreversible benefits (Wesseler 2003). Demont, Wesseler, and Tollens (2004) provide a number of examples illustrating the difference between reversibility and irreversibility.

The different types of benefits and costs are summarized in Table 2.1. Table 2.1 shows a two-dimensional matrix differentiating between reversible and irreversible and private and non-private benefits and costs for an ex ante economic analysis of GM crops. The sum of quadrants one and two gives the value of the net social reversible benefits and that of quadrants three and four the net social irreversible costs. The irreversible costs are of critical importance for biosafety decision-making. They are the major argument supporting biosafety regulations under the Cartagena Protocol on Biosafety (Secretariat of the Convention on Biological Diversity 2000). However, it is not irreversibility itself that has been used exclusively to justify specific biosafety regulations for GM crops as well as to justify a delay in release to obtain additional knowledge and information on the new technology; rather, uncertainty about irreversible costs in combination with uncertainty about the economic benefits of GM crops has been put forward in the Cartagena Protocol and other regulatory processes to justify such interventions.

**Table 2.1. The two dimensions of an ex ante analysis of social benefits and costs of GM crops.**

| Scope | | |
|---|---|---|
| Reversibility | Private | Non-private |
| Reversible | **Quadrant 1** | **Quadrant 2** |
| | Private reversible benefits | External reversible benefits |
| | Private reversible costs | External reversible costs |
| Irreversible | **Quadrant 3** | **Quadrant 4** |
| | Private irreversible benefits | External irreversible benefits |
| | Private irreversible costs | External irreversible costs |

Source: Demont, Wesseler, and Tollens (2004).

In the context of the Cartagena Protocol, the introduction of a new GM crop becomes a decision-making process under uncertainty, irreversibility, and flexibility. Analyzing decision-making under uncertainty, irreversibility, and flexibility is not new to economists and has a tradition in environmental economics that originated in the early 1970s with papers published by Arrow and Fisher (1974) and Henry (1974), while in economics it can even be traced back to Louis Bachelier (1900) (Bernstein 1992). Irreversible benefits and costs in combination with uncertainty and flexibility can be considered within a real option approach for the assessment of the adoption impacts of a GM crop. Examples are provided by Demont, Wesseler, and Tollens (2004) and Scatasta, Wesseler, and Demont (2006) for the introduction of GM strains of sugar beet and corn in the European Union.

*Maximum incremental social tolerable irreversible costs*

We begin with the assumption that incremental reversible net benefits follow a continuous-time, continuous-state process with trend, where GM crops may be released at a point in time. In this approach, the social incremental reversible benefits $W^*$ (the sign * indicates optimal threshold value) need to be greater than the difference between the social incremental irreversible costs ($I$) and the social incremental irreversible benefits ($R$), weighted by the size of the uncertainty and flexibility (or hurdle rate) associated with the introduction of the new technology. The hurdle rate is commonly expressed in the form $\frac{\beta}{\beta-1}$, where $\beta > 1$ captures the uncertainty and flexibility effect and is a result of identifying the profit-maximizing decision rule under irreversibility, uncertainty, and flexibility, if benefits do follow a geometric Brownian motion.[1] The interpretation of the decision rule for the case of a GM banana is that as long as $W - \frac{\beta}{\beta-1}(I - R) \leq 0$, Uganda should delay adoption of a GM banana until more information about the new technology is available.

In the context of GM crops, where people are more concerned about the not-so-well-known irreversible costs of the technology, it is feasible to estimate threshold values that indicate the maximum incremental social irreversible costs that an individual or society in general is willing to tolerate as compensation for the benefits of the technology. Scatasta, Wesseler, and Demont (2006) have called this threshold value the *maximum incremental social tolerable irreversible costs,* $I^*$*,* or MISTICs for short. In the specific case of Uganda, the estimated MISTICs can be interpreted as the maximum willingness to pay (WTP) for not having the GM banana approved for planting in the country. Actual incremental irreversible social costs, *I,* are to be no greater than the sum of incremental irreversible social benefits and incremental reversible social net benefits for introducing a GM banana, such that:

[1] The geometric Brownian motion is a Wiener process with a geometric trend for which changes expressed as natural logarithms are normally distributed. The Wiener process is a continuous-time, continuous-state stochastic Markov process with three properties: (a) probability distributions of future values depend on the current value only; (b) the Wiener process grows at independent increments; and (c) changes are normally distributed. The assumption that the adoption of this technology follows a geometric Brownian motion accounts for the uncertainty of the technology (Cox and Miller 1965).

$$I < I^{*} = \frac{W}{\beta/(\beta-1)} + R \tag{2.1}$$

Using Equation 2.1 with parameter values generated for the case of GM banana can provide threshold values for the irreversible costs. The values can be compared with information from secondary sources to identify whether the threshold value will be met in Uganda.

In practice, estimation of the maximum incremental social tolerable irreversible costs (MISTICs, or $I^{*}$) requires quantification of three factors: social incremental reversible benefits from GM crops (SIRBs, or $W$); social incremental irreversible benefits (SIIBs, or $R$) rate; and hurdle rate, $\beta/(\beta-1)$. All these factors can be estimated or calculated using econometric and mathematical modeling techniques following Demont, Wesseler, and Tollens (2004).

## 2.3 Data and data sources

Secondary data have been used for the estimations of parameters in this chapter. Data are taken from the database of a NARO/IFPRI project conducted between 2003 and 2004 in Uganda. The data set is complemented by data from the Uganda Bureau of Statistics (UBOS) and the Food and Agriculture Organization. Table 2.2 lists the private and non-private reversible and irreversible benefits and costs directly and indirectly considered.

The social incremental reversible benefits (SIRBs) were estimated based on private net benefits. Private incremental reversible benefits can be defined as the difference between the gross margin from GM and non-GM bananas, excluding planting material. Table 2.3 shows the incremental benefits estimations for a GM banana in Uganda. The starting point for these estimations is the gross margin for a non-GM banana crop as reported by Bagamba (2007, p. 31). The annual variable costs for a non-GM banana crop include hired labor used mainly for weeding and crop sanitation. The use of other inputs such as fertilizer and pesticides is, according to Bagamba (2007), negligible. The average output in metric tons per year is about 10.6 per hectare with an average price about 149,600 Uganda shillings (UGX) per metric ton. Under the current production practices, most farmers do not incur costs for planting materials. Most of the planting materials are exchanged for free between farmers (Kikulwe et al. 2007).

**Table 2.2. Social benefits and costs for GM banana considered.**

| Reversibility \ Scope | Private | Non-private |
|---|---|---|
| Reversible | **Quadrant 1**<br>Benefits<br>- Higher yields<br>Costs<br>- Labor costs | **Quadrant 2**<br>Benefits<br>- Zero<br>Costs<br>- Zero |
| Irreversible | **Quadrant 3**<br>Benefits<br>- Negligible<br>Costs<br>- Planting material | **Quadrant 4**<br>Benefits<br>- Indirect: improved food safety and decreased vulnerability<br>Costs<br>- Indirect: possible health and environmental effects |

The average annual gross margin from producing one hectare of non-GM banana (traditional) is approximately UGX 1,411,200 (US$800) excluding labor costs for planting. The main benefit of introducing a GM banana is an increase in banana yield through reduced biotic pressure. Assuming that planting a GM banana with a gene resistant to black Sigatoka[2] increases yield by 20% and labor costs by about 10% and that the average annual costs for planting material are UGX 151,700, the gross margin per hectare would increase from about UGX 1,411,200 to about UGX 1,648,700, or by about UGX 237,500. If the irreversible planting costs are not deducted, the expected average private incremental reversible benefits are about UGX 389,200 per hectare (about US$222 per hectare).

The introduction of a GM banana will trigger an additional cost for planting materials. The total planting costs for about 1,100 plantlets at a price of UGX 1,300 per plantlet are about UGX 1,430,000 per hectare (about US$817). In our computations, we calculated the

[2]In Uganda, black *Sigatoka* reduces yields by 30 to 50 percent (Tushemereirwe et al. 1996; Tushemereirwe et al. 2000) and greatly affects areas with medium and low productivity levels mostly lying in lowlands (below 1200 meters above sea level) of eastern and central Uganda. These areas contribute about two-thirds (64 percent) of the total banana producing areas (Kalyebara, Wood and Abodi 2007)..

**Table 2.3. Incremental gross margin of cultivating one hectare of GM banana (20 percent).**

| Variable | Non-GM banana (matooke)[a] | GM banana (matooke)[b] |
|---|---|---|
| Output (metric tons/year) | 10.6 | 12.7 |
| Price per ton (K) | 149.6 | 149.6 |
| Value of output (K) | 1,504.4 | 1,902.9 |
| Hired labor (hours) | 232.8 | 256.1 |
| Family labor (hours) | 2,295.8 | 2,525.4 |
| Total labor (hours) | 2,528.6 | 2,781.5 |
| Wage rate (UGX/hour) | 400.1 | 400.1 |
| Cost of hired labor (K) | 93.2 | 102.5 |
| Cost of planting materials (K)[a] | 0.0 | 151.7 |
| Gross margin (K) | 1,411.2 | 1,648.7 |
| Return to family labor (UGX/hour) | 614.7 | 652.9 |
| Expected average incremental gross margin (K) | | 237.5 |
| Expected average private incremental reversible benefits (K) | | 389.2 |
| Incremental average return per family labor (UGX/hour) | | 38.2 |
| Total incremental labor income per hectare (K) | | 96.4 |

[a] Source: Bagamba (2007). [b] Source: calculated by authors.

Notes: Benefits and costs are valued in Uganda shillings (UGX 1,750 ≈ US$1, by 2007); return to fixed resources (e.g. land) is not deducted from the gross margin in the computation of return to family labor.

[a] Tushemereirwe, et al. (2003) recommend an average of about 1,100 plantlets per hectare. Due to biosafety requirements, the cost of a GM banana plantlet may at least increase by 30% (UGX 1,300), i.e., from the current UGX 1,000 for a non-GM tissue cultured plantlet.

average annual cost of planting materials using a capital recovery factor for a 10% interest rate and an expected GM banana plant life cycle of 30 years. Furthermore, we assumed no price discount for the GM banana at the farm gate and no other costs of adoption.

## 2.4 Results

### 2.4.1 Social Incremental Reversible Benefits (SIRBs)

The private incremental reversible benefits per hectare were used as the initial value for calculating the SIRBs. To obtain conservative estimates of SIRBs for Uganda, we assume that GM banana adoption follows a logistic function.[3] We used this function to predict what the incremental benefits would be if the GM banana were adopted according to the logistic adoption function. We used an adoption ceiling rate (*K*) of about 50 percent as a proxy for adopting any GM banana cultivar. This rate is based on the predicted demand for nakitembe (a commonly grown cultivar) after effective insertion of genes with 60 percent resistance to both black *Sigatoka* and weevils, with supporting public investments in education, extension, and market-related infrastructure as estimated by Edmeades and Smale (2006). The adoption curve for an adoption ceiling of 50 percent and an estimated speed of adoption of 0.86 in linear form is $p(t) = 3.2 - 0.86t$. Figure 2.1 shows the assumed adoption curve.

The estimation of the *SIRBs* is similar to what would be obtained if a traditional cost-benefit analysis based on a Ricardian rent model is used. But, since the $SIRB_{PV}$ (expected present value of *SIRB*) per hectare are uncertain, we estimated the value of the project under uncertainty by assuming annual *SIRB* follow a stochastic process—geometric Brownian motion. The incremental benefits, the expected future profit flow (*SIRB*), given by $\partial SIRB = (PQ^{GM} - C^{GM}) - (PQ^{non\text{-}GM} - C^{non\text{-}GM})$ follow a geometric Brownian motion. Where $PQ^{GM}$ is the revenue from GM banana, $C^{GM}$ is the cost of production of GM banana, $PQ^{non\text{-}GM}$ is the revenue from non-GM banana, and $C^{non\text{-}GM}$ is the cost of production for non-GM banana. If $SIRB = 0$, there is no extra gain from growing GM banana but the farmer gains income—the farmer gets the same income from GM banana as it is for non-GM banana. The use of the Ricardian rent model can be justified as the parameter estimates used for the calculations are based on time series data reflecting the changes in prices and costs as a result of changes in demand and supply. Including additional demand and supply effects in this case would result in double counting. Further, effects on international trade of banana from Uganda can be ignored as the traditional varieties are not exported and gene transfer between the GM and non-GM banana varieties is not possible considering the biology of banana.

[3] Following Griliches (1957) and Feder, Just, and Zilberman (1985), the adoption curve of a new technology is defined as $\rho(t) = K / 1 + ae^{-bt}$, where $\rho(t)$ is the percentage planted with GM banana in a given year, *K* is the ceiling rate (the long-term upper bound of adoption), *a* is the constant, related to the time when adoption starts, *b* is the speed of adoption, and *t* is the time variable. We transformed the logistic adoption function into its log-linear form: $\rho(t) = \ln\left(\frac{\rho(t)}{K - \rho(t)}\right) = a + bt$. Parameters *a* and *b* were estimated using linear regression.

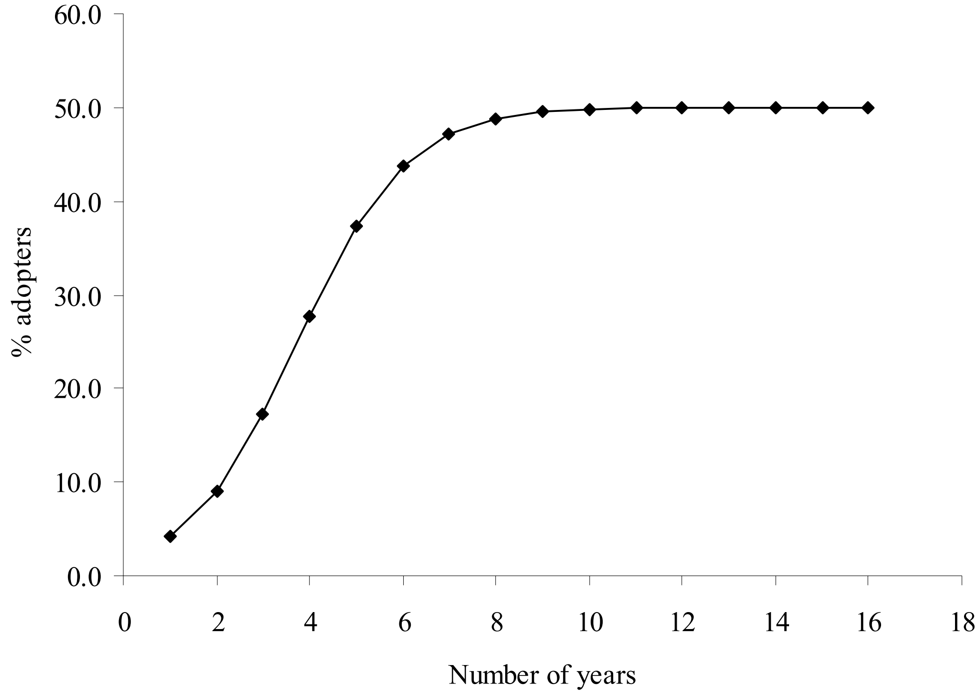



**Figure 2.1. GM banana adoption rate over time.**

We computed the *SIRBs* at time *t* (*SIRB (t)*), as the *SIRBs* at complete adoption times the adoption rate at time *t*, $\rho$ *(t)*, times the expected growth (or drift) at rate *α*: $SIRB(t) = SIRB \cdot \rho(t) \cdot e^{\alpha t}$. The discounted sum of *SIRBs*, $SIRB_{PV}$ for Uganda over time is calculated as:

$$SIRB_{PV} = \int_0^\infty SIRB(t) e^{-(\mu-\alpha)t} dt, \tag{2.2}$$

where $\mu$ is the risk-adjusted discount rate and *α* the drift rate of the geometric Brownian motion, explained in more detail below. The initial value for the calculation of the area for banana production is 1,670,000 hectares at full adoption.

In our analysis, we limit ourselves to the private incremental reversible benefits at the farm level, assuming all the rents from the new technology are captured by farmers. In the longer run, the rents will be distributed among farmers, the agents within the banana supply chain, and banana consumers. Additional secondary benefits such as improved food security and reduced vulnerability to external shocks may be generated through higher farm income among banana growers. Assessing such benefits would require the use of a general equilibrium model for Uganda and be beyond the scope of this study. Thus, the computed SIRBs are equal to the private incremental reversible benefits (PIRBs) and reported in Table 2.4.

**Table 2.4. Average annual SIRBs per banana-growing farm household per hectare at different risk-adjusted rates of return ($\mu$).**

| | **Risk-adjusted discount rates $\mu$** | | | | | |
|---|---|---|---|---|---|---|
| | 0.04 | 0.06 | 0.08 | 0.10 | 0.12 | 0.14 |
| SIRB (million $) | 365 | 304 | 260 | 226 | 200 | 179 |
| SIRB ($/ha) | 459 | 399 | 356 | 326 | 303 | 287 |

Source: calculated by authors.

Note: the exchange rate $1 = UGX 1,750.

The results in Table 2.4 show that the SIRBs, as expected, decrease with an increase in the risk-adjusted rate of return. The estimated SIRBs range between US$365 million and US$179 million per year, or US$459 and US$287 per hectare per year, for the range of risk-adjusted discount rates that varied from 4 percent to 14 percent.

We also tried to identify the social incremental irreversible benefits (SIIBs) on a per hectare basis using information provided by Bagamba (2007). Most banana producers in Uganda do not use pesticides or fungicides to manage pests and diseases, as mentioned earlier. A small proportion (less than a quarter) of banana producers applies small amounts of pesticides.

### 2.4.2 Maximum Incremental Social Tolerable Irreversible Costs (MISTICs)

To estimate the MISTICs for introducing a GM banana, we first calculated the hurdle rate, a measure of irreversibility and uncertainty. The hurdle rate, $\beta/(\beta-1)$, depends on the uncertainty related to the expected SIRBs. Secondary time series data on banana yield per hectare (UBOS 2006b) were used to estimate the drift and variance of the geometric Brownian motion as a proxy for the drift and variance rate from gross margin time series data. The geometric Brownian motion $U = (U_k(t), t \geq 0)$ is a continuous-time, continuous-state stochastic process in which the logarithm of the randomly varying quantity follows a Brownian motion: $U_k(t) = U_0 \exp\left[\left(\lambda - \frac{\sigma^2}{2}\right)t + \sigma W(t)\right]$; where *W(t)* is a Wiener process, $U_0$ is the initial real random number, *t* is the length of equally spaced intervals for all $t \in [0, T]$, and parameters $\lambda$ and $\sigma$ are constants.

The random variables $\log(U_k/U_0) \equiv g_k(t)$ are independently and identically distributed with mean $(\lambda - \sigma^2/2)t \equiv \alpha t$ ($\alpha$ is the expected growth rate or drift) and variance $\sigma^2 t$, where $k = 0,1,...,n$. The maximum likelihood estimators for $\alpha$ and $\sigma^2$ were estimated as follows (see Campbell, Lo, and MacKinlay 1997):

$$\alpha = \frac{1}{nt}\sum_{k=1}^{n} g_k(t) \tag{2.3}$$

$$\sigma^2 = \frac{1}{nt}\sum_{k=1}^{n}\left(g_k(t) - \alpha t\right)^2 \tag{2.4}$$

where *t*, the length of intervals, was one year ($t = 1$), and $n = 24$ years (1980 through 2004). The estimated parameter values were ultimately used to derive hurdle rates for Uganda.

The different hurdle rates, $\beta/(\beta - 1)$, were calculated defining $\beta$ as follows (see Dixit and Pindyck, 1994, pp. 147–52):

$$\beta = \frac{1}{2} - \frac{r - \delta}{\sigma^2} + \sqrt{\left[\frac{r - \delta}{\sigma^2} - \frac{1}{2}\right]^2 + \frac{2r}{\sigma^2}} > 1 \tag{2.5}$$

where *r* is the risk-free rate of return and $\delta$ is the convenience yield defined as the difference between the risk-adjusted discount rate $\mu$ and the drift rate $\alpha$; i.e., $\delta = \mu - \alpha > 0$, $\mu \geq r$, and

$\alpha$ and $\sigma^2$ (variance rate) as before. From the Uganda Bureau of Statistics' data on total area and production of all types of bananas, we estimated the average yield per hectare. Since cooking bananas contribute 80% of total banana production in Uganda, this is a fairly good proxy for the yield of cooking bananas. We estimated a variance rate $(\sigma)$ of 0.0328 and a drift rate $(\alpha)$ of 0.0083 for the yearly difference change for all years from 1980 to 2004. Information about the risk-free rate of return and the risk-adjusted rate of return for farm household investments is rarely available and difficult to calculate.[4] Therefore, hurdle rates were calculated for different risk-free rates of return and risk-adjusted rates of return (0.04, 0.06, 0.08, 0.10, 0.12, and 0.14). Table 2.5 shows the computed annual MISTICs for a GM banana. The MISTICs are presented in total, on a per hectare, per household level, assuming 5,186,558 households as of November 2002 (UBOS 2006a), and per banana-growing farmer, assuming 1,500,000 banana-planting farm households (Kalyebara et al. 2006).

The hurdle rates (Table 2.5) differ as the risk-free rate of return and risk-adjusted rate of return vary. For instance, at $\mu = 0.1$ and $r$=0.04, the hurdle rate is about 1.01. In this case on average every US$1 of incremental social irreversible cost has to match with about 1.01 SIRBs to justify the immediate introduction of the GM banana. In general, the hurdle rates estimated in this chapter are very low compared with other estimates in the literature.

This indicates that the irreversibility effect (Henry 1974) is relatively small and much less important in comparison to other cases studies, where the hurdle rates range between 1.04 and 3.69 (Demont, Wesseler, and Tollens 2004) and 1.03 and 5.6 (Wesseler, Scatasta, and Nillesen 2007). Uganda's production data used to estimate the MISTICs are fairly smooth, in spite of observed biotic shocks in the 1990s and other years. Damage in a particular year may have been localized, yet heavy in those localized areas, so that national averages smooth out variations.

The annual MISTICs decrease as well with an increase in the risk-adjusted rate of return and with an increase in the risk-free rate of return. At $\mu = 0.10$ and $r$ = 0.04, MISTICs are about US$224 million per year, or about US$322 per hectare per year. The MISTICs per banana-growing (farm) household and those per household (non-producing household)

[4] Mithöfer (2005) is a notable exemption. The author estimated risk-adjusted rate of returns for farmers investment in planting indigenous fruit trees in Zimbabwe ranging on average between 13.00 and 15.64 percent.

**Table 2.5. Hurdle rates, average annual MISTICs per hectare of GM banana, per household, and per banana-growing farm household at different risk-free rates of return (r) and risk-adjusted rates of return (μ).**

| Risk-free rate of return ($r$) | | Risk-adjusted rates of return ( $\mu$ ) | | | | | |
|---|---|---|---|---|---|---|---|
| | | 0.04 | 0.06 | 0.08 | 0.10 | 0.12 | 0.14 |
| | Hurdle rate | 1.0169 | 1.0104 | 1.0075 | 1.0059 | 1.0048 | 1.0041 |
| | MISTIC (million $) | 359 | 301 | 258 | 225 | 199 | 178 |
| 0.00 | MISTIC ($/ha) | 451 | 394 | 353 | 324 | 302 | 285 |
| | MISTIC ($/household) | 69 | 58 | 50 | 43 | 38 | 34 |
| | MISTIC ($/farmer) | 239 | 201 | 172 | 150 | 133 | 119 |
| | Hurdle rate | 1.3298 | 1.0405 | 1.0166 | 1.0103 | 1.0075 | 1.0058 |
| | MISTIC (million $) | 274 | 293 | 256 | 224 | 198 | 178 |
| 0.04 | MISTIC ($/ha) | 345 | 383 | 350 | 322 | 301 | 285 |
| | MISTIC ($/household) | 53 | 56 | 49 | 43 | 38 | 34 |
| | MISTIC ($/farmer) | 183 | 195 | 170 | 149 | 132 | 119 |
| | Hurdle rate | | | | 1.1386 | 1.0355 | 1.0161 |
| | MISTIC (million $) | | | | 199 | 193 | 176 |
| 0.10 | MISTIC ($/ha) | | | | 286 | 293 | 282 |
| | MISTIC ($/household) | | | | 38 | 37 | 34 |
| | MISTIC ($/farmer) | | | | 132 | 129 | 118 |

Source: calculated by authors.

Note: the exchange rate $1 = UGX 1,750, in the year 2007.

indicate a large difference between the two groups. The MISTICs per farm household are more than three times larger than the MISTICs per household. As indicated previously, the MISTICs can be interpreted as the maximum willingness to pay for not having a GM banana approved for planting in Uganda. Therefore, the difference in the MISTIC values between Farm households and non-banana-producing households—both urban and rural—shows that in general the average banana-growing household may have a much larger interest than an average Ugandan household in having access to a GM banana even if the banana-growing household is concerned about the irreversible costs.

## 2.5 Conclusions and policy implications

In this study we have presented an approach for considering concerns about genetically modified crops within a socioeconomic analysis of GM crops. We calculated the MISTICs associated with the adoption of a GM banana in Uganda. The MISTICs were presented for different risk-free and risk-adjusted rates of return. The results show the MISTICs to be between approximately US$176 million and US$359 million per year, or between US$282 and US$451 per hectare per year. In the scenario with a risk-adjusted rate of return of 12 percent and a risk-free rate of interest of 4 percent, which we consider to be a reasonable scenario based on the results of Mithöfer (2005), the annual MISTICs per household are about US$38. This result can be interpreted as follows: the immediate release of the GM banana should be postponed or abandoned only if the average household is willing to give up more than US$38 per year for not having such a banana introduced.

In the case where approval of the GM banana is delayed due to missing regulatory procedures and protocols, Uganda will forego potential benefits (social incremental reversible benefits, or SIRBs) in the approximate range of US$179 million to US$365 million per year. This foregone benefit can be an indicator of how much Uganda can pay to compensate for potential damages. Additionally, the SIRBs provide a clue about the maximum costs farmers would endure in order to comply with biosafety regulations, including the cost of implementing coexistence policies and after deducting planting costs of US$101 per hectare. In a reasonable scenario, for instance, the average SIRBs total about US$303 per hectare. Adopters of the GM banana would not be willing to pay more than US$200 per hectare per year in transaction costs—i.e., costs to comply with biosafety regulations, R&D costs, and technology transfer costs. Assuming a maximum of 541,530 hectares that may be planted in GM banana in Uganda, this implies that the maximum total costs to bring the GM banana to Ugandan producers cannot exceed US$108 million. Otherwise, the GM banana is not a viable alternative.

The analyses in this chapter demonstrate the economic value and the effect of the foregone benefits as a result of waiting to release a GM banana. The results illustrate several implications to numerous stakeholders. First, the calculation of the MISTICs considers explicitly possible long-term effects of GM banana. The results indicate that with each year of delay in the introduction of a GM banana, Uganda loses about US$179 million to US$365 million to all households in Uganda. The MISTICs are in the order of about US$176 million or more. Only if the real average annual irreversible costs of planting a GM banana would be as high as, or higher than, the irreversible benefits should the release be delayed. We have found no evidence yet that this will be the case. Given the potential and significant economic benefits from the introduction of a GM banana, NARO has to work harder to push the GM banana through the biosafety protocols as promptly and efficiently as possible.

Second, our findings indicate that a banana-growing household may have a much (three times) larger interest in having access to a GM banana than an average Ugandan household. This can be explained by the great losses experienced by farm households due to the prevailing banana constraints. The losses caused by banana constraints, therefore, make the opportunity cost to farmers of not using the GM banana technology extremely high. This implies that a farm household would naturally benefit disproportionately from a GM banana technology that is likely to ensure a return to sustainable production.

Third, biosafety regulatory assessment, and its posterior analysis, has to overcome the observed tendency of most regulatory processes globally of avoiding committing regulatory errors during decision-making and particularly stacking the odds in favor of not approving technologies that are safe against approving a technology that is not safe. In essence, decisions made by most regulatory bodies tend to be more precautionary than warranted. To ensure a more balanced approach to decision-making, the literature suggests consideration of all benefits and costs—including opportunity and irreversible—supporting regulatory decision-making. This chapter proposes one alterative approach in this line of reasoning.

Lastly, the approach used here highlights how one can evaluate the socioeconomic aspects of GM crops in general. To those stakeholders who are pessimistic about such technologies, it shows how much benefits are foregone as a result of a delayed release of a given technology. We have also indicated how one can consider long-term irreversible effects of GM crops. The approach can therefore be adapted to new GM crops requiring biosafety assessments prior to commercialization and can help to overcome one of the problems of establishing a biosafety system for Uganda or other African country.

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# Chapter 3

# Consumer Knowledge, Attitudes, and Perception towards and Awareness and Trusts in Regulation of GM food: the Case of Genetically Modified Banana in Uganda[♦]

[♦] A version of this chapter has been **submitted** to *Food Policy* as: Kikulwe, E., J. Wesseler, and Falck-Zepeda, J. Consumer Knowledge, Attitudes, and Perception towards and Awareness and Trusts in Regulation of GM food: the Case of Genetically Modified Banana in Uganda.

## Abstract

Despite the skepticism towards genetically modified (GM) crops, Uganda, as many other African countries, recognizes GM crops as having a great potential for promotion of human well-being by meeting the critical needs for food. However, the global negative concerns about GM crops could impede public acceptance of biotechnology products in the country. As little is known about consumer knowledge, attitudes and perceptions (KAP) toward GM banana in Uganda, a survey was conducted among 421 banana-consuming households. We applied an explanatory factor analysis to investigate the underlying latent structure of the KAP data. Three distinct categories of consumer KAPs were identified, including benefit, food and environmental risk, and health risk of GM crops and food. Results show rural consumers value the tangible benefits, while urban consumers are more concerned about the safety of GM crops and food, indicating a rural-urban bias. While this is a disturbing observation as mainly rural households economically gain from the introduction of a GM banana crop, a careful approach towards introducing GM banana is needed to avoid strong urban consumer resistance.


**Key words***:* GM banana; knowledge; attitudes; perceptions; biosafety; Uganda

## 3.1 Introduction

In his recent book, Paarlberg (2008) argues urbanized policy elites in Africa are stereotypically European and far removed from their own rural poor. Modern crop biotechnology is not reaching farmers in Africa because most governments there, following the regulatory practice of European countries, have made it difficult for such crops to be planted. Similarly, Herring (2008) argues International Non-Governmental Organizations do press their preferences on low-income countries. Except for Egypt, Burkina Faso and South Africa no other African country has approved transgenic crops for planting yet (James 2008). If it is true African governments follow the European model do they act against the preferences of their own consumers?

Although there is a large number of studies on consumer acceptance of GM crops and derived foods worldwide, especially in the USA (Curtis et al. 2004; Chen et al. 2002), Europe(Dannenberg, Scatasta, and Sturm 2009; Einsele 2007; Curtis et al. 2004), Canada (Hu et al. 2004), Australia (Owen et al. 2005), Latin America (Curtis et al. 2004; Mucci et al. 2004) and Asia (Krishna and Qaim 2008; Curtis et al. 2004; Kim and Kim 2004; Zhang et al. 2004; Li et al. 2002) little is known on consumers' knowledge, attitudes and perceptions toward GM food in Africa. Kimenju and De Groote (2008) in a willingness-to-pay study among consumers in Nairobi do find most consumers (68 percent) would buy GM maize meal if offered at the same price as a comparable non-GM maize meal. Despite this study research on consumer knowledge, attitudes and perceptions towards food and awareness and trust in the regulation of GM food in Africa is missing.

To investigate how Ugandan consumers perceive the introduction of GM crops, a study was conducted among 421 banana-consuming households with the aim of exploring their knowledge, attitudes, and perceptions (KAPs) and institutional awareness in relation to the introduction of a GM banana. The introduction of a GM banana was chosen as it is an important food crop and among the first GM crops to be introduced in Uganda. GM bananas are currently undergoing a confined field trial. The transgenic trait is resistant against the air-borne fungal black leaf spot disease or "black Sigatoka" (*Mycosphaerella fijiensis)*. The chosen modified bananas are local cooking bananas because they are the most widely grown ones and highly preferred among consumers.

This chapter is structured as follows. In section 3.2, we describe the methodology of the study. Section 3.3 reports the results. The final section discusses the findings and draws conclusions for the introduction of GM banana and GM crops in general.

## 3.2 Methods and materials

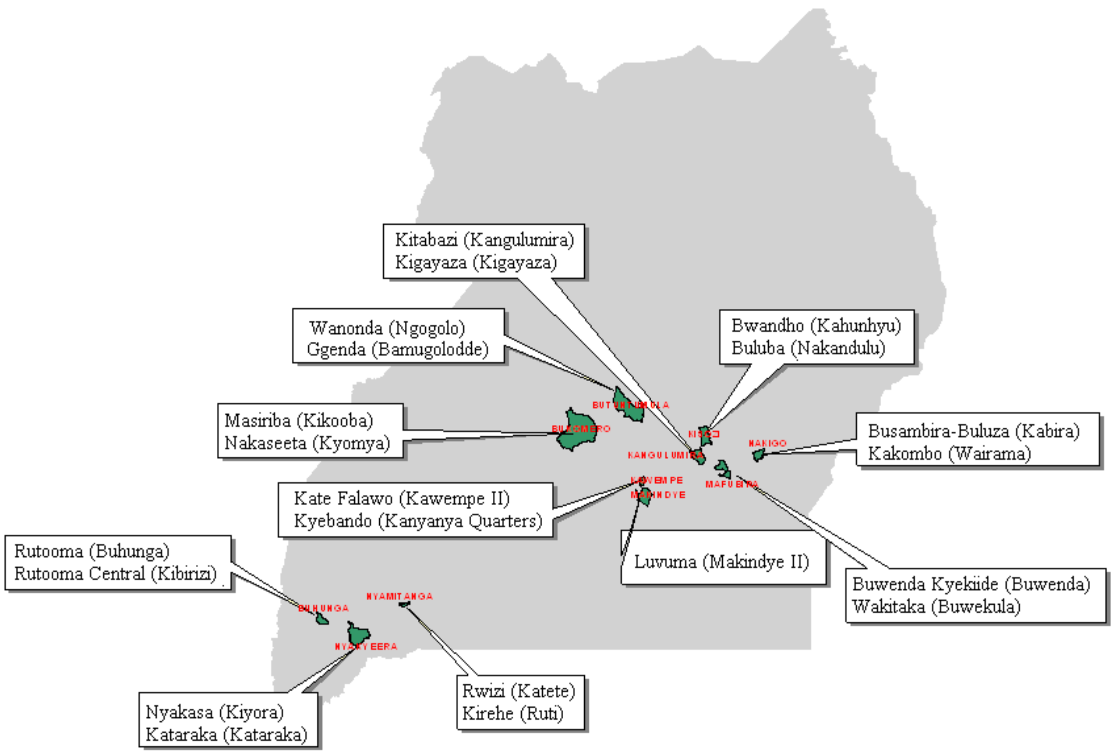
### 3.2.1 Study sites

The study was conducted in different regions in Uganda where cooking bananas are produced and consumed, including urban areas that are mainly sole consumers of bananas. The sample domain was purposively selected to represent the major banana-consuming regions: Eastern Region, Central Region, and Southwestern Region. The sample was drawn using a multistage sampling procedure, and stratified into rural and urban consumers. The primary sampling unit (PSU) was a sub-county for rural areas and a division for urban areas. A total number of 11 PSUs was selected, with seven in rural and four in urban areas. The criterion for selection was based on the distribution of the Ugandan population (UBOS 2006a).

The secondary sampling unit was the village. At sub-county/division level, two parishes were randomly selected for the survey. In each parish, one village (community) was drawn using a systematic random sampling criterion with a random start. Within each community, households were randomly selected from a current community listing. The final sample consisted of 21 villages, with 14 in rural and 7 in urban areas. Urban communities were sampled from the three main cities (Kampala, Mbarara and Jinja), with Kampala—the capital city and most densely populated—having three communities while the others shared the rest equally. In total 421 randomly selected households were interviewed across 21 communities in three regions of Uganda. The final representation of all the primary and secondary sampling units is shown in figure 3.1.

### 3.2.2 Data collection and analysis

The study was implemented in July and August 2007 with face-to-face interviews. Prior to the interviews, respondents were informed about biotechnology and biosafety in Uganda. This was done using information on brochures which were provided by the Consumer Education Trust (CONSENT), which is mandated by the Uganda National Council of Science and Technology (UNSCT) to promote biotechnology awareness campaigns in the country. The information included the various aspects of biotechnology such as; biotechnology and biosafety concepts, definitions, benefits, and public concerns for GM crops, and how scientists and the government are likely to handle public concerns. Respondents were also informed about the ongoing activities in the National Agricultural Research Organization (NARO), where scientists are trying to improve a non seed producing banana cultivar for perseverance to pests and diseases using cell culture and genetic transformation of the plant.




Note: areas in parentheses are parishes where selected communities are located.

**Figure 3.1. Location of study sites.**

Data was collected using a formal questionnaire pre-tested on both rural and urban communities. Six enumerators were hired and trained specifically for this study. Data collected included three different parts: consumer characteristics, consumers' knowledge, attitudes and perceptions (KAP) toward GM banana, GM food in general, and GM crops and awareness and trust in organizations handling regulation and control of production, sale and release of the aforementioned. The questionnaire and the information provided to the respondents are provided in the appendices of the thesis.

Consumers were asked 22 questions to assess their KAP. Consumers' KAP were measured by asking respondents if they strongly agreed or disagreed with 22 statements. All responses were coded using a Likert scale from 1 to 5 with 1 for strongly disagree and 5 strongly agree.

The KAP questions overlap and can reflect more than one motivational concern toward GM food and crops. Principal factor analysis with Crawford-Ferguson rotation was performed to develop scales based on linear combination of statement responses that have similar patterns of variation across the sample into an appropriate factor solution. The results of this analysis indicate that the most appropriate solution involved three factors (Table 3.1). The criteria for acceptability of a factor solution were based on: (1) minimum factor membership of four items[1]; (2) exclusion of items with factor loadings less than 0.40 (Birol et al. 2007; Kontoleon 2003); and (3) minimum factor eigenvalues of 1.0. A comparison analysis revealed that the extraction of three factors was in accord with the standard acceptability criteria. The scree test and the number of eigenvalues greater than 1 support the decision to accept a three factor solution. An orthogonal Crawford-Ferguson rotation specifying a three-factor solution accounted for 93 percent of the common variance—with factor 1 accounting for 36 percent; factor 2, 30 percent and factor 3, 27 percent—suggesting that each factor represents an important factor of the consumer KAP. Cronbach's alpha coefficients were computed to give an indication of the internal consistency of each factor. Values were found to be moderate to high, displaying the homogeneity of each factor.

Factor naming was based on variables that factored together and the relative magnitude of the loadings in absolute terms. The first factor termed as "benefit KAP" (BKAP) had high loadings on questions related to approval and potential benefits of GM crops. This category of KAPs captures the tendency of a consumer to support a GM crop (food) based on its various potential benefits (e.g. price, nutrition, less chemical use, and taste). The second factor labeled "food-environment risk KAP" (FKAP) had high loadings on

[1] Fabrigar et al. (1999) recommend that for the explanatory factor analysis results to be more accurate, it is sensible to include at least four measured variables for each common factor.

**Table 3.1. Factor analysis loadings for consumers' answers to KAP questions.**

| Item no. | 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 loadings | | |
|---|---|---|---|---|
| | | 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 percent) | 36 | 30 | 27 |
| | Cronbach's alpha coefficient | 0.80 | 0.69 | 0.56 |

Note: loadings in bold are values of 0.4 and above.

statements that reflected consumer concerns on food and environmental safety. The food-environment risk KAP refers to concerns over the impact of GM foods or human interference on the status of the food and environment. The third factor that had high loadings on health safety was called "health risk KAP" (HKAP). Health risk KAP reflects concerns over the likely—long-term but unknown—effects of GM food toward health safety in general.

Factor scores for each factor were obtained for each household. The KAP scores were then compared against consumer characteristics in their respective localities. For BKAP scores, higher positive values indicate a greater liking of GM food and crops, particularly GM banana. While, higher positive values of both FKAP and HKAP scores indicate higher levels of concern over food-environment safety and health risk issues respectively. The significance of differences between urban and rural households was established using multiple-comparison tests (F-test) and two group mean-comparison tests (T-test) (at $\leq$ 10% significance level).

## 3.3 Results

### 3.3.1 Consumer characteristics

Most respondents (75 percent) were household heads responsible for decision-making on what to grow, consume, buy or sell. Nearly a half of the households were located in the Central Region, while the Eastern Region and Southwestern Region shared the rest equally. At least 43 percent of respondents were women, with more than half in urban areas. Respondents averaged 41 years of age, with younger ones located in urban areas. Education differed significantly, with urban areas having a higher proportion of respondents with secondary education. The size of banana-consuming households is, on average, six persons, with urban areas having relatively smaller-sized households. More than half of the respondents had at least one family member working off-farm, with a significantly higher percentage in urban areas. About a half of the rural households had a monthly income of less or equal to UGX 50,000, whereas the majority of the urban households had an average monthly income of more than UGX 200,000.

Survey data confirm the high level of banana production in rural areas (96 percent), with an average farm size of about 0.6 hectares. Though urban consumers are considered as sole consumers, a relatively large proportion of households (49 percent) also produced banana owning on average 0.2 hectares. Sole banana consumers, households who only buy but not

**Table 3.2. Consumer characteristics.**

| Characteristic | Location | | |
|---|---|---|---|
| | Rural | Urban | All |
| | Mean | | |
| Average age (years)* | 42.20 (15.90) | 37.90 (13.90) | 40.80 (15.36) |
| Average education of respondent (years)* | 6.30 (4.10) | 9.00 (4.70) | 7.20 (4.47) |
| Household size* | 6.40 (3.30) | 5.50 (3.50) | 6.10 (6.11) |
| Area under banana (hectares)* | 0.57 (0.75) | 0.22 (0.57) | 0.45 (0.71) |
| | Percent | | |
| Female respondents* | 36.6 | 56.4 | 43.2 |
| At least a member employed off-farm* | 39.1 | 81.4 | 53.2 |
| Education levels* | | | |
| Never | 13.5 | 10.0 | 12.4 |
| Primary | 58.7 | 31.4 | 49.6 |
| Secondary | 22.4 | 40.0 | 28.3 |
| College/University | 5.4 | 18.6 | 9.7 |
| Total | 100.0 | 100.0 | 100.0 |
| Monthly income levels[1] * | | | |
| UGX ≤50,000 (low) | 47.0 | 20.7 | 38.2 |
| UGX 50,001 to 200,000 (medium) | 38.8 | 34.3 | 37.3 |
| UGX >200,000 (high) | 14.2 | 45.0 | 24.5 |
| Total | 100.0 | 100.0 | 100.0 |
| Regional distribution of households | | | |
| Eastern Region | 28.5 | 28.6 | 28.5 |
| Central Region | 43.1 | 42.8 | 43.0 |
| Southwestern Region | 28.5 | 28.6 | 28.5 |
| Total | 100.0 | 100.0 | 100.0 |
| Banana production and consumption* | | | |
| Only grows | 21.0 | 8.5 | 16.9 |
| Only buys | 4.3 | 50.7 | 19.7 |
| Grows and sells | 32.4 | 7.9 | 24.2 |
| Grows and buys | 29.9 | 25.0 | 28.3 |
| Grows, sells and buys | 12.4 | 7.9 | 10.9 |
| Total | 100.0 | 100.0 | 100.0 |

Notes: standard deviations are in parentheses. *indicates significant differences between means and or distributions of rural and urban households at the 10 percent level or better based on a single t-test. [1]The three income categories were developed based on UBOS (2006c) income class differentials, which indicate that 41 percent of the Ugandan households belong to the lowest income group.

grow banana, are more common among urban households (51 percent) than rural ones (four percent). A third of the households surveyed sell at least one banana bunch per year, with a higher share among rural households (45 percent). A detailed description of the consumer characteristics of the banana-consuming households for the sample is presented in Table 3.2.

### 3.3.2 Consumer knowledge, attitudes and perceptions (KAP) towards GM banana

Results indicate that there were significant differences in mean scores by regions, particularly in the rural areas (Table 3.3). In the central and eastern rural areas, respondents scored significantly higher for BKAP compared to the Southwestern Region. On the contrary, urban respondents in the same regions scored significantly lower for BKAP compared to their counterparts in the rural areas. No significant differences were exhibited between regions among rural and urban households for both food-environment and health risk KAPs. However, urban consumers in the Central Region and Eastern Region scored significantly higher for HKAP compared with their rural counterparts. Urban men exhibited significantly lower scores for BKAP compared to women, but between locations rural men scored significantly higher than their urban counterparts. For FKAP, urban women scored significantly higher than men and rural women. Likewise, urban women scored higher for HKAP than men and HKAP scores significantly differed between rural and urban women. While both rural women and men scored significantly lower for HKAP. Results suggest that urban women have relatively higher scores on both FKAP and HKAP compared to men.

Respondents with college or university education scored much lower for BKAP in both rural and urban areas, but significantly differed from other education levels only among rural households. Rural respondents with primary and secondary education levels scored higher for BKAP, which significantly differed from scores exhibited by their urban counterparts. Urban respondents with no education scored higher for BKAP, which significantly differed from the lower scores for urban respondents with college or university education. For FKAP and HKAP, there were no significant differences regarding education status. Across locations, however, respondents with secondary education in urban areas scored significantly higher than their rural counterparts for FKAP. Likewise, urban respondents with primary education significantly differed from those with the same education in the rural areas for HKAP. In addition, though not significantly different, highly educated respondents in both rural and urban areas scored highest for HKAP. Results reveal that highly educated respondents exhibited the highest level of concern for HKAP and lowest for BKAP compared to less educated respondents exhibited the highest level of concern for HKAP and lowest for BKAP compared to less educated ones.

**Table 3.3. Comparison of KAP scores with consumer characteristics.**

| | Mean KAP scores | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | Benefit | | | Food-environment risk | | | Health risk | | |
| Characteristic | Rural | Urban | Test | Rural | Urban | Test | Rural | Urban | Test |
| Regions. | | | | | | | | | |
| Central | 0.18[a] | -0.15[a] | * | -0.08[a] | 0.10[a] | | 0.04[a] | 0.28[a] | * |
| Eastern | 0.34[a] | -0.27[a] | * | -0.12[a] | 0.10[a] | | -0.15[a] | 0.23[a] | * |
| Southwestern | -0.25[b] | 0.02[a] | | 0.03[a] | 0.02[a] | | -0.22[a] | 0.02[a] | |
| P-value | 0.00 | 0.45 | | 0.53 | 0.90 | | 0.32 | 0.27 | |
| Gender | | | | | | | | | |
| Men | 0.10[a] | -0.39[b] | * | -0.08[a] | -0.07[b] | | -0.03[a] | 0.13[a] | |
| Women | 0.11[a] | 0.06[a] | | -0.02[a] | 0.19[a] | * | -0.28[b] | 0.28[a] | * |
| P-value | 0.87 | 0.01 | | 0.60 | 0.09 | | 0.02 | 0.31 | |
| Education status | | | | | | | | | |
| Never | -0.02[a] | 0.31[a] | | -0.05[a] | -0.31[a] | | -0.14[a] | 0.04[a] | |
| Primary | 0.15[a] | -0.08[ab] | * | -0.05[a] | -0.02[a] | | -0.21[a] | 0.10[a] | * |
| Secondary | 0.23[a] | -0.14[ab] | * | -0.11[a] | 0.23[a] | * | 0.03[a] | 0.21[a] | |
| College above | -0.69[b] | -0.45[b] | | 0.08[a] | 0.13[a] | | 0.31[a] | 0.41[a] | |
| P-value | 0.00 | 0.15 | | 0.89 | 0.17 | | 0.05 | 0.40 | |
| Income levels. | | | | | | | | | |
| Low | 0.20[a] | -0.33[a] | * | -0.09[a] | -0.22[a] | | -0.05[a] | 0.17[a] | |
| Medium | -0.02[b] | 0.11[a] | | 0.02[a] | 0.17[a] | | -0.12[a] | 0.09[a] | |
| High | 0.13[ab] | -0.24[a] | * | -0.15[a] | 0.14[a] | | -0.34[a] | 0.28[a] | * |
| P-value | 0.09 | 0.19 | | 0.48 | 0.12 | | 0.16 | 0.48 | |
| At least a member employed off-farm | | | | | | | | | |
| Yes | -0.05[b] | -0.06[a] | | -0.15[a] | 0.10[a] | * | -0.16[a] | 0.16[a] | * |
| No | 0.20[a] | -0.48[b] | * | -0.001[a] | 0.01[a] | | -0.10[a] | 0.32[a] | * |
| P-value | 0.01 | 0.06 | | 0.16 | 0.59 | | 0.57 | 0.36 | |
| Banana status | | | | | | | | | |
| Grow only | 0.07[ab] | -0.01[a] | | -0.12[a] | 0.003[a] | | -0.16[a] | 0.17[a] | |
| Buy only | 0.45[ab] | -0.21[a] | * | 0.07[a] | -0.01[a] | | -0.23[a] | 0.28[a] | * |
| Grow and sell | -0.05[b] | -0.12[a] | | 0.02[a] | 0.46[a] | | 0.02[a] | 0.32[a] | |
| Grow and buy | 0.27[a] | -0.02[a] | * | -0.10[a] | 0.05[a] | | -0.33[a] | 0.13[a] | * |
| Grow, sell & buy | -0.02[ab] | -0.19[a] | | -0.10[a] | 0.38[a] | | 0.11[a] | -0.26[a] | |
| P-value | 0.03 | 0.91 | | 0.89 | 0.39 | | 0.03 | 0.30 | |

Notes: * denotes significance at the 10 percent level or better. In columns, means followed by the same letter are not significant at the 10 percent level or better (Sidak multiple-comparison test in STATA).

Furthermore, low and high income earners in rural areas scored higher for BKAP but only low and medium income earners differed significantly. In urban areas no significant differences were exhibited between the three income categories, albeit low and high income earners scored lower for BKAP compared to medium income earners. Results further reveal that between locations rural low and high income earners scored significantly higher compared to their urban counterparts. The results suggest that low and high income earners in rural areas are much more positive towards BKAP in comparison to low and high income earners in urban areas.

No significant differences were revealed between income groups and FKAP and HKAP in both rural and urban areas, but high income earners in urban areas scored significantly higher than their rural counterparts for HKAP. Furthermore, households with at least one member working off-farm in both rural and urban areas scored significantly lower for BKAP than those households without. For FKAP and HKAP, urban respondents scored higher than rural ones. The results suggest that urban respondents expressed more concerns about risks than benefits of GM crops.

Finally, rural households that only grow or buy plus those that both grow and buy bananas scored higher for BKAP compared to those that either grow and sell or grow, sell, and buy. However, significant differences were only observed between households that grow and sell and those that grow and buy. Across location, respondents who buy only and those who grow and buy scored significantly higher for BKAP than their urban counterparts. For FKAP and HKAP, there were no significant differences among rural and urban households, but urban households scored relatively higher than rural households. Across locations, however, urban respondents who buy banana and those who grow and buy scored significantly higher for HKAP than rural respondents. Results imply that urban sole consumers and those few who grow and buy are more concerned about the health risks than the benefits the technology may provide. This would mean that the KAP scores are significantly different.

### 3.3.3 Factors influencing GM banana purchase

To determine the most important factors that influence choice, consumers were asked to rate five product characteristics—price, taste, nutrition, health safety, and environmental safety — according to their level of importance prior to purchasing a GM banana. The rating again was based on a Likert scale ranging from strongly disagree (1) to strongly agree (5).

The definition of the “most important factor” was defined by the number of consumers responding to the top (4-5) scale levels, i.e., agree and strongly agree. Results show that on average, taste (89 percent), price (76 percent) and nutrition (62 percent) are the most important factors (Figure 3.2), while health and environmental safety are the least.

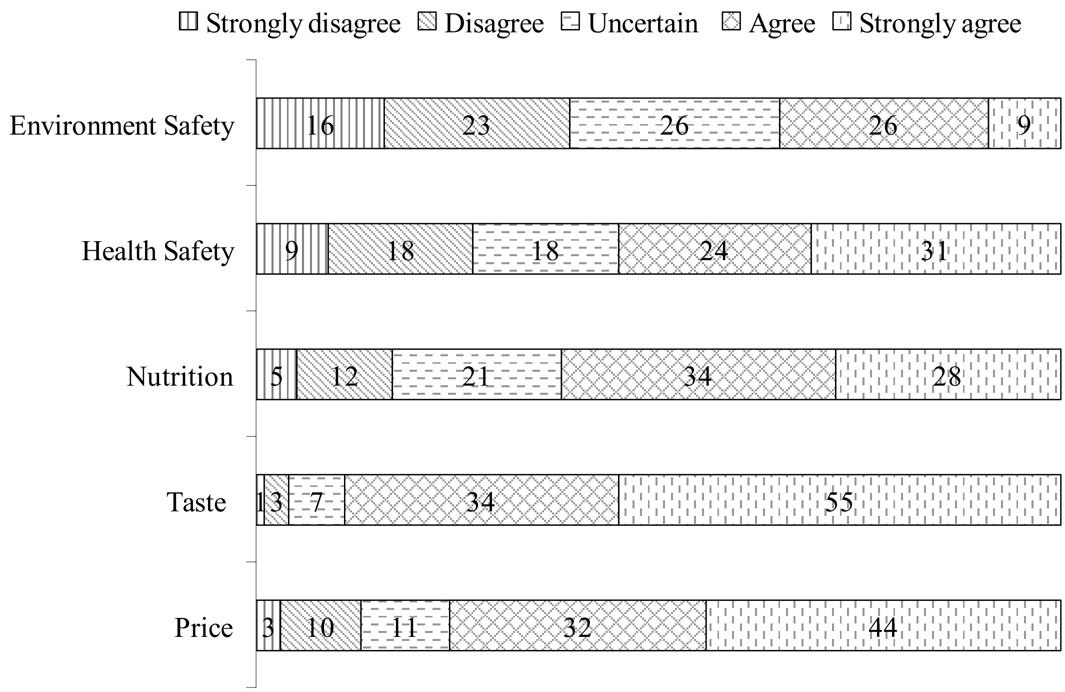



**Figure 3.2. Factors influencing food purchasing behaviors of consumers.**

Note: numbers represent the percentages of respondents.

A chi square test analysis of the socio-demographic variables (age, gender, education, income) with the three most important factors yielded no significant differences. We further examined the three most important factors to investigate how they affect consumer willingness to purchase a GM banana. Consumers were asked to indicate their willingness to purchase a GM banana if offered: at a discount; at a premium; at the same price but more nutritious (vitamin and iron), used less chemicals and tasted better (Figure 3.3). Results indicate that even without tangible benefits, over three-quarters (78 percent, i.e., agree and strongly agree) of consumers were willing to purchase GM banana at a discount. But, if a higher price is charged, only slightly more than a third (39 percent) would buy GM banana. This indicates a high acceptance of GM banana (technology) at a discount but reduces to half if offered at a higher price. Interestingly, with tangible benefits—e.g. contained vitamins and iron, less pesticides applications, and better taste - but sold at the same price as the non-GM banana, more than three quarters were willing to purchase GM banana.

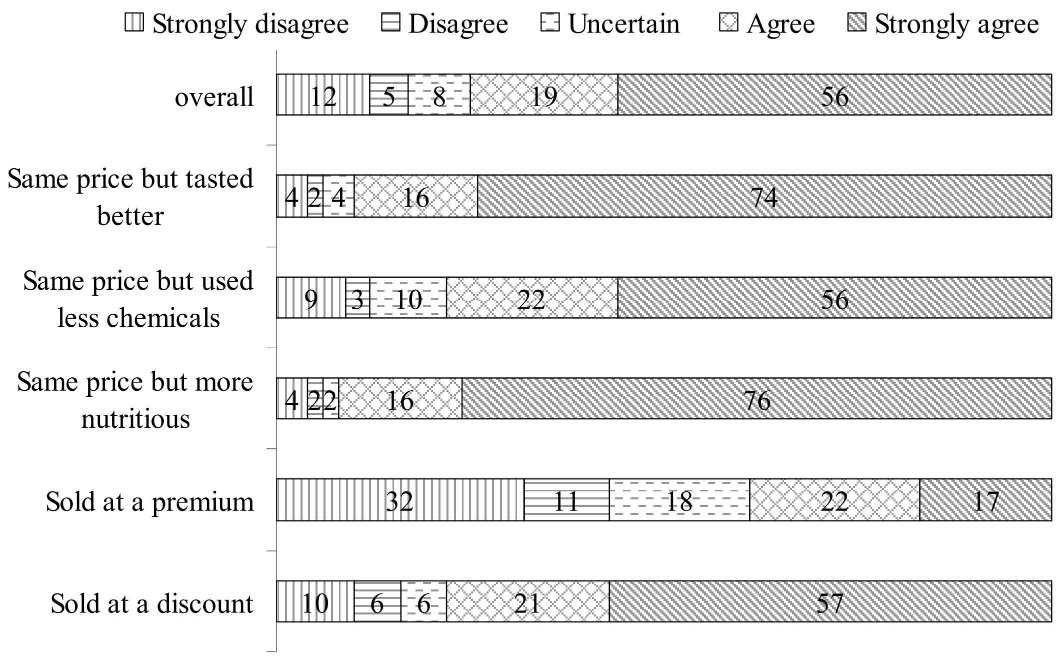



**Figure 3.3. Consumers' willingness to buy GM banana offered at the same price, at a premium, or at a discount for different scenarios.**

Note: numbers represent the percentages of respondents.

### 3.3.4 Consumer awareness and trust

To understand the level of awareness of the institutions involved in regulation and control of production, sale and release of foods, beverages and seed, each respondent was requested to indicate whether s/he knew or heard of each of the mentioned institution ("Awareness"). For known or heard of institutions each respondent was asked to complete the subsequent three trust questions:

- Do you have confidence that the named institution can control production of food or crops that could be harmful to people ("Trust not produce")?
- Do you have confidence that the named institution can prevent harmful products to be sold in shops, supermarkets and restaurants ("Trust not sell")?

- Do you have confidence that the named institution can control release of crops that could be harmful to the environment ("Trust not release")?

Each question had three alternatives, "yes" (if trust in an institution), "no" (if not trusted), and "don't know" (if a respondent is not certain). Only responses which indicated awareness of an institution are reported in Table 3.4.

Most respondents knew their area local leaders, politicians (e.g. members of parliament, district representatives) and the ministry in charge of agriculture, animal industry and fisheries (MAAIF). The least known were the two private institutions, the Consumer Education Trust **(**CONSENT) and Agro-genetic Technologies (AGT), and one important public institution, Uganda National Council of Science and Technology (UNCST). MAAIF, local leaders, and extension workers at district and sub-county levels were the most trusted institutions in relation to not allowing production of crops that could be harmful to the people, while UNBS, URA and food processors were the least trusted. CONSENT and UNBS were the most trusted institutions for not allowing sale of harmful products in shops, supermarkets and restaurants, whereas URA and National Environment Management Authority (NEMA) are the least trusted. Lastly, as for the institutions that could not allow release of organisms (foods) that could be harmful to the environment, NEMA, MAAIF, National Agricultural Advisory Services (NAADS) and local leaders had the highest confidence levels among respondents. The least confidence were exhibited among URA, UNBS and AGT. Interestingly, the two private institutions with the task to inform the population about biotechnology, CONSENT and AGT, are the least known with awareness of about 17 and 12 percent, respectively. While they are not well known among those knowing the institutions, they are relatively well trusted.

## 3.4 Discussion and conclusions

The results indicate that across the surveyed households three categories of consumer knowledge, attitudes, and perceptions (KAPs) toward GM crops and food were identified: benefit, food-environment risk and health risk KAPs. Rural consumers in both the Central Region and Eastern Region of Uganda scored higher for BKAP compared to the Southwestern Region and their urban counterparts. A possible explanation is in both regions banana production is

**Table 3.4. Respondents awareness of and trust in institutions responsible for control or regulation of GM crops and food in Uganda.**

| Institution | N | Awareness | | | trust not produce | | | trust not sell | | | trust not release | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | rur | urb | all | rur | urb | all | rur | urb | all | rur | urb | all |
| | | Percent | | | percent | | | percent | | | percent | | |
| Loc. lead. | 419 | 100 | 98.8 | 99.5 | 86.4 | 82.5 | 85.1 | 67.4 | 58.8 | 64.6 | 80.5 | 73.9 | 78.4 |
| Ext. work. | 328 | 84.3 | 65.0 | 77.9 | 84.7 | 72.8 | 81.3 | 50.4 | 34.1 | 45.9 | 79.7 | 64.8 | 75.5 |
| NARO | 219 | 45.9 | 64.3 | 52.0 | 69.8 | 70.1 | 70.0 | 45.9 | 39.8 | 41.3 | 76.0 | 69.0 | 73.1 |
| UNFFE | 203 | 47.3 | 50.0 | 48.2 | 71.4 | 70.0 | 70.9 | 42.1 | 42.9 | 42.4 | 74.1 | 69.6 | 72.5 |
| NAADS | 342 | 84.0 | 75.7 | 81.2 | 83.0 | 76.2 | 80.9 | 45.8 | 39.1 | 43.7 | 81.7 | 71.3 | 78.6 |
| UNBS | 300 | 64.4 | 85.0 | 71.3 | 43.4 | 53.4 | 47.3 | 81.1 | 86.4 | 83.2 | 39.7 | 34.9 | 37.6 |
| URA | 376 | 86.1 | 95.7 | 89.3 | 25.0 | 26.3 | 25.5 | 35.6 | 40.2 | 37.3 | 25.3 | 20.8 | 23.7 |
| Univ. Sci. | 209 | 45.2 | 59.4 | 50.3 | 68.0 | 66.3 | 67.3 | 60.9 | 44.3 | 54.6 | 72.4 | 57.0 | 66.5 |
| Food pro. | 301 | 67.3 | 80.0 | 71.5 | 51.4 | 48.2 | 50.2 | 51.7 | 49.1 | 50.7 | 42.5 | 38.9 | 41.1 |
| MOT | 294 | 65.5 | 78.6 | 69.8 | 49.4 | 56.9 | 52.3 | 65.5 | 59.3 | 63.2 | 46.6 | 47.2 | 46.8 |
| MAAIF | 406 | 94.7 | 100 | 96.4 | 90.6 | 86.3 | 89.1 | 67.7 | 61.1 | 65.4 | 89.7 | 83.8 | 87.7 |
| NEMA | 366 | 83.6 | 93.6 | 86.9 | 73.3 | 61.8 | 69.2 | 39.2 | 38.2 | 38.8 | 93.1 | 82.4 | 89.2 |
| Politicians | 418 | 99.6 | 98.8 | 99.3 | 58.6 | 56.2 | 57.8 | 53.3 | 36.0 | 47.6 | 61.6 | 50.0 | 57.8 |
| NGOs | 364 | 87.9 | 83.6 | 86.5 | 66.4 | 53.4 | 62.3 | 54.1 | 42.6 | 50.4 | 66.5 | 53.1 | 62.3 |
| UNCST | 103 | 22.1 | 29.3 | 24.5 | 69.4 | 74.4 | 71.4 | 60.3 | 52.3 | 57.0 | 69.8 | 67.4 | 68.9 |
| Coops | 350 | 84.3 | 80.7 | 83.1 | 66.5 | 60.0 | 64.4 | 53.8 | 45.9 | 51.2 | 60.0 | 52.8 | 57.7 |
| UTA | 221 | 47.3 | 62.9 | 52.5 | 51.1 | 60.9 | 55.0 | 57. 1 | 66.7 | 60.9 | 42.3 | 43.0 | 42.6 |
| CONSENT | 73 | 17.4 | 17.1 | 17.3 | 77.6 | 60.0 | 71.6 | 81.3 | 62.5 | 75.0 | 70.2 | 50.0 | 63.4 |
| AGT | 46 | 12.1 | 8.6 | 11.3 | 69.4 | 41.7 | 62.5 | 44.4 | 58.3 | 47.9 | 61.1 | 41.7 | 56.2 |

Notes: N= total number of respondents who knew the mentioned institution; Loc. Lead. = local leaders; Ext. work. = extension workers; NARO = National Agricultural Research Organization; UNFFE =Uganda National Farmers Federation; NAADS= National Agricultural Advisory Services; UNBS= Uganda National Bureau of Standards; URA = Uganda Revenue Authority; Univ. Sci. = University Scientists; Food pro. = Food processers; MOT=Ministry of Trade; MAAIF= Ministry of Agricultural Animal Industries and Fisheries; NEMA=National Environment Management Authority; NGOs = Non-Governmental Organizations; UNCST=Uganda National Council of Science and Technology; Coops = Cooperatives; UTA=Uganda Traders Association; CONSENT= Consumer Education Trust; AGT= Agro-genetic Technologies; rur = rural; urb = urban.

constrained by biotic pressures resulting in lower yields. The results imply that the Eastern Region and Central Region are more likely to adopt a GM banana compared to the

Southwestern Region. This is similar to the findings of Edmeades and Smale (2006) who report farmers in regions greatly affected by biotic pressures are more likely to have higher demands for planting materials of a GM host cultivar.

The KAP for urban consumers did not differ significantly between regions, though in the Central Region and Eastern Region urban consumers scored higher for FKAP and HKAP, indicating risk concerns about GM bananas, especially regarding future health. Urban women were found to be more likely to accept GM banana compared to men, however, they were also concerned about the potential negative impacts of the technology for food and environment safety (FKAP). Higher educated consumers (college level and above) with at least one member of their households working off-farm—both in rural and urban areas—as well as high income earners (particularly in urban) are more unlikely to accept GM food as a result of their perceived future health concerns. The results indicate further that higher educated people seem to be more critical towards new technologies and in particular GM food. This may have negative implications for the introduction of GM banana as higher educated people are often opinion leaders. For the introduction of a safe GM banana and the introduction of GM food and crops in general the government has to pay attention to informing the better educated part of the population "to get them on board".

Furthermore, if a household grows banana and supplement its production with market-bought banana bunches, the household is generally more likely to accept GM bananas because of the benefits, specifically in rural areas. But households - both rural and urban - that grow and sell banana were more skeptical about GM bananas. The reason could be that since these households are targeting urban consumers, they perceive growing GM bananas could lead to loss of their potential market. Results imply that in general, a banana-producing household that grow and buy banana has a much larger interest in accessing GM bananas than an average non-banana growing household (sole consumer). The negative perception of sole consumers is similar to what is reported for the European Union and Japan (Einsele 2007; McCluskey et al. 2003).

Price and quality—measured as taste and nutrition—are the most important factors that influence consumer choice when shopping for banana in Uganda. This is in line with results in the EU (European Commission 2006), where European consumers considered quality (42 percent) and price (40 percent) as the most important factors when purchasing food. Our results further indicate that even without higher quality benefits, there was a high level of acceptance for GM banana (75 percent) at a discount but this reduced to half if offered at a premium. When offered with quality benefits such as better taste and more nutritious but at the same price as the traditional (non-GM) banana, over three-quarters of the households would be willing to purchase GM banana, indicating high acceptance of GM banana. This implies that in general, about 75 percent of the banana-consuming households in Uganda would be willing to buy GM banana for their household members, similar to the findings of Kimenju and De Groote (2008) who found that most consumers (68 percent) were willing to buy GM maize meal at the price of their favorite maize meal in Nairobi, Kenya. Similar positive acceptance is reported by other studies, e.g. in India (Krishna and Qaim 2008), US (Curtis et al. 2004; Chen et al. 2002), China (Zhang et al. 2004; Li et al. 2002), the Philippines (Curtis et al. 2004) and Colombia (Curtis et al. 2004).

Furthermore, there was a very low awareness of institutions that are responsible for education, distribution, and regulation of production and sale of GM products. Only 17 percent of the respondents were aware of the Consumer Education Trust (CONSENT) a private NGO responsible for creating public awareness of biotechnology and biosafety in Uganda. 11 percent of the households were aware of Agro-genetic Technologies (AGT) limited, a company responsible for multiplication and distribution of GM tissue cultured plantlets. Roughly a quarter of all households knew the Uganda National Council of Science and Technology (UNSCT), yet it is the public body responsible for implementing biotechnology and biosafety policy in Uganda. In contrast, the results show high proportion of awareness of local leaders and politicians and the ministry of agriculture, animal industry and fisheries (MAAIF). Interestingly, consumers exhibited more confidence among community local leaders and public food, agricultural or environment related organizations such as MAAIF, extension workers, UNBS, NEMA, and NAADS in controlling and regulating production, sale, and release of GM food and crops compared to private institutions. The strong confidence in public authorities among banana consumers is similar to that in other countries such as the EU (European Commission 2006) and Australia (Owen et al. 2005). In both studies most consumers agreed that public authorities particularly health and food related institutions are doing enough with respect to regulating GM crops and foods. A clear implication from these results is that the Ugandan government needs to be at the forefront of addressing the potential concerns of the GM technology.

The KAP toward GM crops among rural and urban consumers vary owing to a number of socioeconomic characteristics, suggesting a rural-urban bias. Moreover, given tangible benefits, consumers are more willing to accept GM banana but at the same time they are concerned about the unknown negative effects of the technology. Nonetheless, the level of awareness of organizations responsible for regulation of GM products is low, yet consumers have much trust in the government's ability to regulate the production, release and sale of GM crops and food in Uganda.

The positive mean FKAP and HKAP scores among the urban population and their partially negative BKAP scores indicate this group of consumers to be concerned about GM banana but also most likely about GM food in general. The relatively high level of awareness and trust in local leaders and extension workers and the low awareness of UNCST and CONSENT, the two main agencies responsible for informing consumers about GM food, presents an opportunity for informing consumers' about GM food through local leaders and extension workers. Instead of UNCST and CONSENT informing consumers directly they may also use part of their resources for training local leaders and to enlist their help in spreading information. Government policies delaying the introduction of genetically modified bananas are more in line with the views of wealthier and better educated citizens, the elites, than with the views of the majority of the population. While this is a disturbing observation as mainly rural households economically gain from the introduction of a safe GM banana crop, a careful approach towards introducing GM banana is needed to avoid strong urban consumer resistance.

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# Chapter 4

# Rural Versus Urban Preferences for Banana Attributes in Uganda: Is there a Market for GM Staples?[♦]

♦ An earlier version of this chapter with only rural consumers will be published as: Kikulwe, E., E. Birol, J. Falck-Zepeda, and J. Wesseler. *Forthcoming (2010)*. Rural consumers' preferences for banana attributes in Uganda: Is there a market for GM staples? In J.W. Bennett and E. Birol, eds. *Choice experiments in developing countries: Implementation, challenges and Implications,* Cheltenham: Edward-Elgar, UK.

## Abstract

This chapter investigates heterogeneity in the preferences in banana bunch attributes. Choice modeling application was undertaken to understand rural and urban consumers' preferences for different banana attributes for a disease resistant GM banana. The chapter applies a random parameter logit model, which does not assume the independence of irrelevant alternative (IIA) property, and detects unobserved, unconditional preference heterogeneity. The results indicate preference heterogeneity among rural and urban households. In general, rural households have a higher WTP for the attribute benefits for producers of GM banana than urban households, but the WTP decreases with an increase in income. However, if consumers have higher education, they are more likely to be critical toward the GM technology. Implications for introducing GM banana in Uganda are discussed.

**Keywords:** choice experiment, preference heterogeneity, random parameter logit model, GM banana, Uganda

## 4.1 Introduction

Banana is one of the most important staple crops in Uganda. Approximately seven million people, or 26 percent of the population, depend on the crop as a source of food and income. Bananas are planted on 1.5 million hectares of the total arable land, which amounts to 38 percent of the cultivated land in the country (Rubaihayo and Gold 1993; Rubaihayo 1991). Ugandans have the highest per capita consumption of cooking banana in the world (Clarke 2003).

Several diseases affect banana yields in Uganda. Among the diseases that contribute to the worst yield losses are the soil-borne fungal Panama disease, or *Fusarium* wilt (*Fusarium oxysporum*), bacterial wilts including the banana *Xanthomonus* wilt (*Xanthomonus campestris* pv. *musacearum*), and the air-borne fungal black leaf spot disease or 'black Sigatoka' (*Mycosphaerella fi jiensis* Morelet) (Tushemereirwe et al. 2003; Gold et al. 2001; Gold 2000).

In the mid-1990s, the Uganda National Banana Research Program of the National Agricultural Research Organization (NARO) launched its long-term research program using conventional breeding and genetic engineering methods to improve banana productivity. The aim of the genetic engineering methods is to develop genetically modified (GM) varieties that are resistant to local diseases, have improved agronomic attributes, and are acceptable to consumers (Kikulwe et al. 2007).

Concerns about compliance with biosafety regulations, as well as potential environmental and food safety risks can be important obstacles to public acceptance of biotechnology products in Africa (Paarlberg 2008). Therefore the introduction of GM bananas in Uganda is likely to generate a wide set of concerns (Kikulwe et al. 2008).

The aim of the study presented in this chapter is to investigate the effect of preference heterogeneity on consumers' valuation for a GM banana that is resistant to diseases. The choice experiment (CE) method is employed since GM bananas are currently undergoing a confined field trial and hence they are not yet marketed in Uganda. The banana attributes included in the CE were the size of the bunch, variety (GM or otherwise), benefits the variety might generate for the banana farmers, and price per bunch. Four hundred-and-twenty-one households in both rural and urban areas of the three regions in Uganda were interviewed.

The rest of this chapter is structured as follows. The next section presents the theoretical framework of the CE method. Section 4.3 explains the CE design and its administration, including the study sites and descriptive statistics of the sample. The results are reported and discussed in section 4.4, and the chapter concludes with discussions on the implications of the results for the introduction of GM bananas in Uganda.

## 4.2 The choice experiment approach

The choice experiment (CE) method has its theoretical grounding in Lancaster's model of consumer choice (Lancaster 1966), and its econometric basis in random utility theory (RUT) (Luce 1959; McFadden 1974). To illustrate the basic model behind the CE presented here, consider a consumers' choice of a banana bunch. The banana bunch is characterized by a number of attributes such as size, price, and others which can have different levels. A number of banana bunch alternatives can be formed based on the attributes and their levels. Assume that utility depends on choices made from a choice set *C*, which includes all possible banana bunch alternatives. For any consumer $i$, a given level of utility will be associated with any banana bunch alternative $j$. Utility derived from any of the banana bunch alternatives depends on the attributes of the banana bunch (expressed in vector $Z$), such as the size of the bunch or its variety. According to RUT, the utility of a choice is comprised of a deterministic component $V$ and an error component $e$ which is independent of the deterministic part and follows a predetermined distribution. The consumer has a utility function of the form:

$$U_{ij} = V(Z_{ij}) + e(Z_{ij}) \tag{4.1}$$

The error component implies that predictions cannot be made with certainty. Choices made between alternatives will be a function of the probability that the utility of consumer $i$ associated with a particular banana bunch $j$ is higher than those for other alternatives. Assuming that the relationship between utility and attributes is linear in the parameters and variables function, and that the error terms are identically and independently distributed with a Weibull distribution, the probability $P_{ij}$ of any particular banana bunch alternative $j$ being chosen by household $i$ can be expressed in terms of a logistic distribution, which takes the general form:

$$P_{ij} = \frac{\exp(V(Z_{ij}))}{\sum_{h=1}^{C} \exp(V(Z_{ij}))} \tag{4.2}$$

where $V$ is the conditional indirect utility function, which can be estimated with a conditional logit model (CLM) (Maddala 1999, pp. 42; Greene 1997, pp. 913–914; McFadden 1974) and generally estimated as:

$$V_{ij} = \beta + \beta_1 Z_1 + \beta_2 Z_2 + ... + \beta_n Z_n \tag{4.3}$$

where $\beta$ is the alternative specific constant (ASC) which captures the effects on utility of attributes not included in choice-specific banana bunch attributes, $n$ is the number of banana bunch attributes considered, and $\beta_1$ to $\beta_n$ is the vector of coefficients associated with the vector of attributes $Z$.

The assumptions about the distribution of error terms that are implicit in the use of the CLM impose a particular condition known as the independence of irrelevant alternatives (IIA) property. IIA states that the relative probabilities of two alternatives being chosen are unaffected by the introduction or removal of other alternatives from the choice set $C$. If the IIA property is violated, then CLM results will be biased (Louviere et al. 2000; Rolfe, Bennett, and Louviere 2000). Another problem of directly applying CLM is that preferences are assumed to be homogeneous across consumers.

One solution to both problems is to include interactions of consumer-specific characteristics with banana bunch attributes in the utility function. First, this captures heterogeneous consumer preferences and enhances the accuracy and reliability of estimates of demand and marginal welfare (Greene 1997). Second, the inclusion of social and economic consumer characteristics also helps to avoid IIA violations, since social and economic characteristics relevant to the preferences of the consumers can increase the systematic component of utility while decreasing the random one (Rolfe, Bennett, and Louviere 2000; Bateman et al. 2003). Furthermore, accounting for heterogeneity provides insights about differences in consumer valuation of the GM technology in addition to understanding the aggregate economic value associated with such technology, similar to the policy-change effect as analyzed by Boxall and Adamowicz (2002).

Another solution is to model preference heterogeneity via a random parameter component to the vector of coefficients $\beta$s called a random parameter logit model (RPLM), or a mixed logit model. Compared to the CLM, the RPLM does not require the IIA assumption and can also account for unobserved, unconditional heterogeneity in preferences across respondents even when conditional heterogeneity has been considered as well as correlation among choices arising from the repetition of choices by the same respondent (Garrod, Scarpa, and Willis 2002; McFadden and Train 2000). The random utility function in the RPLM is given by:

$$U_{ij} = V(Z_j(\beta + \eta_i)) + e(Z_j) \tag{4.4}$$

Similarly to the CLM, utility is decomposed into a deterministic component $V$ and an error component stochastic term $e$. Indirect utility is assumed to be a function of the choice attributes $Z_j$, with the utility parameter vector $\beta$, which due to preference heterogeneity may vary across respondents by a random component $\eta_i$. By specifying the distribution of the error terms $e$ and $\eta$, the probability of choosing $j$ in each of the choice sets can be derived (Train, 1998). By accounting for unobserved heterogeneity, the random parameter logit model takes the form:

$$P_{ij} = \frac{\exp(V(Z_j(\beta + \eta_i)))}{\sum_{h=1}^{C} \exp(V(Z_h(\beta + \eta_i)))} \tag{4.5}$$

Since this model is not restricted by the IIA assumption, the stochastic part of utility may be correlated among alternatives and across the sequence of choices via the common influence of $\eta_i$. Treating preference parameters as random variables requires estimation by simulated maximum likelihood. The maximum likelihood algorithm searches for a solution by simulating $k$ draws from distributions with given means and standard deviations. Probabilities are calculated by integrating the joint simulated distribution.

Even though unobserved heterogeneity can be accounted for in the RPLM, this model fails to explain the *sources* of heterogeneity (Boxall and Adamowicz 2002). One solution to detecting the sources of heterogeneity while accounting for unobserved heterogeneity could be to include interactions of respondent-specific household characteristics with choice-specific attributes in the utility function. The RPLM with interactions can detect preference variation in terms of the unconditional heterogeneity of tastes (random heterogeneity) and individual characteristics (conditional heterogeneity), so improving the fit of the model (Morey and Rossmann 2003; Revelt and Train, 1998).

When the interaction terms are included in the utility function, the indirect utility function that is estimated becomes (Rolfe, Bennett, and Louviere 2000):

$$V_{ij} = \beta + \beta_1 Z_1 + \beta_2 Z_2 + ... + \beta_n Z_n + \delta_1 (Z_1 S_1) + \delta_2 (Z_2 S_2) + ... + \delta_l (Z_n S_m) \quad (4.6)$$

In this specification, $m$ is the number of consumer-specific characteristics that explain the choice of a banana bunch, and $\delta_1$ to $\delta_l$ is the $l$-dimensional matrix of coefficients corresponding to the vector of interaction terms $S$ that influence utility. Since consumer-specific characteristics are constant across choice occasions for any given consumer, consumer characteristics only enter as interaction terms with the banana bunch attributes.

Recent applications of the RPLM (e.g. Carlsson, Frykblom and Liljenstolpe 2003; Kontoleon 2003; Morey and Rossmann 2003; Breffle and Morey, 2000) have revealed that this model is superior to conditional logit model in terms of overall fit and welfare estimates. In this chapter, therefore, RPLM was applied. This was followed by RPLM including interactions of respondent-specific characteristics with banana bunch attributes to provide more information about the sources of variations in preferences across respondents. CLM has also been applied. The results are presented in the appendix 4A, indicating IIA violation.

## 4.3 Choice experiment design and administration

### 4.3.1 Choice sets

The most important banana bunch attributes and their levels were identified in consultation with experts and agricultural scientists at the National Banana Research Program of NARO, 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 and their levels, as well as their coding for analysis, are reported in Table 4.1.

In Uganda, bananas are typically sold in bunches. The first attribute, bunch size, therefore represents the average size of a banana bunch at harvest, which varies from small to large. The majority of the banana bunches currently sold (64 percent) are small as they are from traditional varieties that are endemic to Uganda (Edmeades 2007).

**Table 4.1. Attributes, their definitions, and levels for choice sets.**

| Attributes | Definitions | Levels | Coded using |
|---|---|---|---|
| Bunch size | The average size of a banana bunch at harvest | Small<br>Medium<br>Large | Dummy variables |
| Benefit | The magnitude of the expected increase in the incomes of banana producers | None<br>Medium<br>Large | Dummy variables |
| Biotechnology | The type of biotechnology used to produce the banana planting material | Traditional<br>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 second attribute, benefit in Ugandan shillings (UGX), was included in the CE to test the hypothesis that consumers may derive utility from gains made by GM banana producers as suggested by Portney (1994) in addition to those related to the quality/quantity of the private good (i.e., banana).

The third attribute represents the type of technology 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 includes both traditional and modern biotechnology. Traditional biotechnology may include products of tissue culture or micro-propagation, while modern biotechnology uses for example, DNA diagnostic probes, recombinant DNA, functional and structural genomics and other methods for plant breeding (Falck-Zepeda 2009). Currently, most banana-producing households in

Uganda grow local cultivars of East African highland cooking bananas, while GM cooking banana generated through the application of modern biotechnology are not yet available[1].

The last attribute, price, portrays hypothetical percentage changes in the price of a banana bunch, which is included in order to estimate consumers' WTP.

One hundred and eight unique banana profile descriptions can be constructed from this number of attributes and levels. Statistical design methods (see Johnson et al. 2007; Kuhfeld 2004; Louviere et al. 2000) were used to structure the presentation of the levels of the four attributes in choice sets. Following Johnson et al. (2007) and Kuhfeld (2004), a D-Optimal choice experimental design was constructed with only the main effects using the SAS software. It is important to note that in the context of a CE, the goal is not to come up with a balanced and orthogonal design. Rather the goal is to generate a design that has maximum efficiency given the assumed specifications for attributes coefficients and all the other properties of the experiment (Kuhfeld 2004). A fraction of a full-factorial design was used to construct an efficient design with 16 choice sets[2].

During the survey, each respondent was presented with 16 choice sets, each containing two banana profiles and an option to 'opt out' by selecting neither of the banana profiles. Choosing 'opt out' meant that the respondent would purchase the current traditional variety. Figure 4.1 provides an example of a choice set.

The CE study was implemented in Uganda, in July and August 2007 with face-to-face interviews. Data were collected using a formal questionnaire, which was pre-tested and revised accordingly. Six enumerators were hired for five days and trained specifically for this study. During training, each enumerator had the chance to interview at least one respondent while others were recording the responses and challenges faced. After the training, discussions were held in order to improve the choice experiment. Prior to the interviews, respondents were informed about biotechnology and biosafety in Uganda. This was done using information from the brochures that were provided by the Consumer Education Trust

[1] The visual aids used in the survey to inform respondents regarding the diseases of bananas are available from the authors on request.

[2] The experimental design requires four attributes with a full factorial of 108. If we estimate a model that treats all levels as categorical, we need a minimum of 2*(3-1) +1*(2-1) +1*(6-1) +1 = 11 degrees of freedom, which corresponds to a minimum of 11 choice sets (called a "saturated" design). We adopted 16 choice sets since bigger designs are generally preferred to improve model flexibility and statistical power (Johnson et al. 2007).

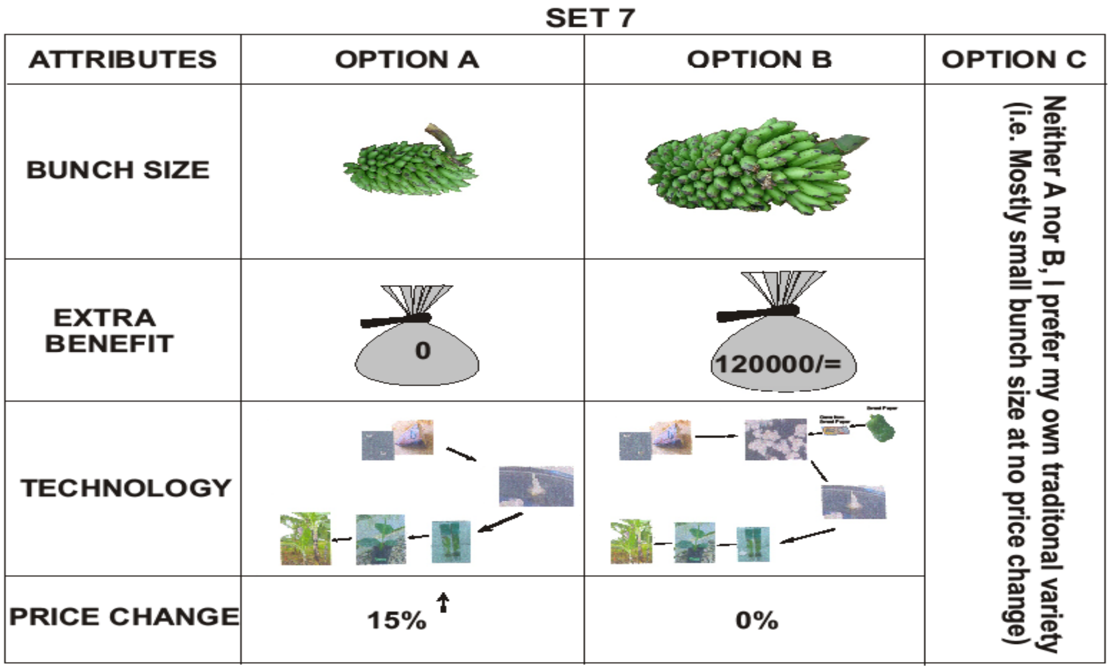


**Figure 4.1. Sample choice set**

(CONSENT), a non-governmental organization, mandated by the Uganda National Council of Science and Technology to promote biotechnology awareness campaigns in the country. The brochures were in the local languages spoken in the study areas. In addition to the information from CONSENT, respondents were also informed about the on-going activities of NARO, where scientists are trying to develop a disease-resistant banana cultivar using genetic modification. Finally, respondents were informed about the context in which the choices were going to be made, a detailed description of the attributes used, as well as the status quo. An imaginary scenario was presented to respondents assuming that, on the day of the survey, the respondent was out of banana and shopping to restock. Respondents were asked to choose one bunch options out of each of the 16 choice sets presented.

Respondents were reminded that there were no right or wrong choice. Enumerators used illustrated and laminated visual aids for each choice set in order to explain the attributes, levels they take and the status quo, explicitly and clearly. Data on respondents' social and economic characteristics were collected as well.

### 4.3.2 Study sites

The study was conducted in three different regions in Uganda where cooking bananas are produced and consumed. These three regions were purposively selected to represent the major banana-consuming regions in Uganda, and they included the Eastern Region, Central Region, and Southwestern Region. The survey sample was drawn using a multistage sampling procedure, and stratified into urban and rural locations. The final sample consisted of 21 communities across these three regions. A total of 421 randomly selected households, representing a response rate of 84.2 percent, were interviewed. This high response rate was achieved as a result of the face-to-face survey mode chosen. Social and economic characteristics of households are reported in Table 4.2 by location.

Overall, there were more men (63 percent) than women in the sample. The majority of respondents were household heads responsible for making decisions on what to grow, buy or sell. Over 40 percent of the households were located in the Central Region, while equal numbers of households were interviewed in the Eastern Region and Southwestern Region. The sample sizes are proportional to the population size in each region. The age of respondents differs between the two locations. On average, respondents had attained seven years of education, i.e. primary level, with urban consumers having on average more years of formal education compared to their rural counterparts.

The size of households differs significantly across the two locations, with larger households being located in the rural areas. A significantly higher percentage (81 percent) of households in the urban areas has at least one household member working off-farm. Respondents' average monthly income differs statistically, with rural households having almost a third of the monthly income of urban ones. Almost all (96%) of the rural households are banana producers, whereas only half of urban banana consumers also grow banana. As expected, households in urban areas farm smaller banana acreages. Urban households are also significantly more likely to be banana buyers and less likely to be banana sellers.

According to the latest census (UBOS 2006c), the average household size in rural Uganda is 5.3 whereas in the urban areas this figure is 4.1. A large proportion (44 percent) of rural households have off-farm employment with an average income of approximately UGX 143,000, compared to more than a half (51 percent) in urban areas who earn roughly UGX 306,300 as off-farm incomes. A small proportion of households are female-headed (27 percent) and a large group (80 percent) of household heads having at least primary education (Uganda Bureau of Statistics 2006c). In comparison to the population statistics, the random sample of our study shows on average larger household size, lower household income for rural and slightly higher for urban households, a higher percentage of female headed households and a higher level of education.

# 4.4 Results

## 4.4.1 Random parameter logit model

The CE was designed with the assumption that the observable utility function would follow a strictly additive form. The model was specified so that the probability of selecting a particular banana bunch is a function of banana bunch attributes and the ASC, which takes the form:

$$V_{ij} = \beta + \beta_1(Z_{BUNMED}) + \beta_2(Z_{BUNLAR}) + \beta_3(Z_{BENMED}) + \beta_4(Z_{BENLAR}) + \beta_5(Z_{GMTEC}) + \beta_6(Z_{PRICE}) \quad (4.7)$$

where $\beta$ refers to the alternative specific constant (ASC), which was equaled to 1 if either option A or B was chosen and 0 if the respondent chooses the status quo (option C) (Louviere et al. 2000)[3], $Z_{BUNMED}$ is the medium bunch size, $Z_{BUNLAR}$ large bunch size, $Z_{BENMED}$ medium benefit, $Z_{BENLAR}$ large benefit, $Z_{GMTEC}$ GM biotechnology, and $Z_{PRICE}$ percent price change.

The simulated maximum livelihood estimates for the random parameter logit model (Train 1998) that allows for correlation between taste parameter are reported in Table 4.3[4]. GM biotechnology and large benefits for farmers were the only variables entered as random parameters and assumed to be normally distributed (Train 1998; Revelt and Traian 1998; Carlsson et al. 2003), while medium benefit, medium bunch size, large bunch size and price

[3] A fairly more negative and significant ASC indicates a higher tendency of the respondent to choose the status quo

[4] The correlation matrix is not included here but a test of correlations between variables indicated that correlations only existed between the levels of the same variables, not individual variables indicating no multicollinearity.

were fixed, i.e., assumed homogeneous[5]. Using the 6736 choices elicited from 421 consumers, random parameter logit models were estimated for the pool of the two locations and for each location separately with LIMDEP9.0 NLOGIT4.0 utilizing 500 draws for the distribution simulations.

**Table 4.2 Consumer characteristics by location**

| Characteristic | Rural (N=281) | Urban (N=140) | All (N=421) |
|---|---|---|---|
| | | Mean | |
| Age of the household head*** | 42.24 (15.88) | 37.85 (13.87) | 40.78 (15.36) |
| Education (years)*** | 6.34 (4.08) | 8.97 (4.70) | 7.21 (4.47) |
| Number of household members *** | 6.44 (3.27) | 5.45 (3.22) | 6.11 (3.28) |
| Monthly household income (UGX 1000)*** | 119.55 (225.66) | 345.67 (485.48) | 194.75 (351.18) |
| Banana acreage in hectares *** | 0.57 (0.75) | 0.22 (0.57) | 0.45 (0.71) |
| | | Percent | |
| At least one member of the family works off farm*** | 39.10 | 81.40 | 53.20 |
| Household grows banana*** | 95.70 | 49.30 | 80.30 |
| Household buys banana *** | 46.60 | 83.60 | 58.90 |
| Household sells banana*** | 44.80 | 15.70 | 35.10 |
| Households in Eastern Region | 28.50 | 28.60 | 28.50 |
| Households in Central Region | 43.10 | 42.80 | 43.00 |
| Households in Southwestern Region | 28.50 | 28.60 | 28.50 |

Note: standard deviations are in parentheses. ***denotes significance at the 1 percent level or better.

The RPLM estimates both the mean coefficient and standard deviation of the random parameters. It is imperative to note that: first, if the standard deviation estimate is not significantly different than zero, then one can conclude that the preference parameter is

[5] In this study, all choice attributes were first specified as random parameters and allowed all coefficients to vary normally (price could also be + or -, premium or discount since GM is a controversial good). That is, we first assumed that consumers may like or dislike any of the banana bunch attributes presented to them in the choice experiment. The model with all the attributes randomized failed to converge and consequently it was tested down to include only GM and large benefit attributes.

**Table 4.3. Random Parameter Logit Model for pooled, rural and urban samples.**

| Samples | Coeff. | Coeff. Std. |
|---|---|---|
| **Pooled** | | |
| *Random Parameters in Utility function* | | |
| GM biotechnology | 0.86*** (0.12) | 1.50***(0.11) |
| Large benefit | 0.16** (0.08) | 0.01 (0.28) |
| *Non-Random Parameters in Utility function* | | |
| ASC | 1.20*** (0.10) | |
| Medium bunch size | 0.46*** (0.02) | |
| Large bunch size | 0.66*** (0.04) | |
| Medium benefit | 0.13*** (0.02) | |
| Price (% change) | -0.02***(0.00) | |
| Log likelihood at start | -5366.39 | |
| Simulated log at log likelihood | -5264.47 | |
| Likelihood ratio test 203.8 ($\chi^2_{0.99}(13)$) = 27.7, McFadden's $\rho^2$ = 0.286. | | N = 6736 |
| **Rural** | | |
| *Random Parameters in Utility function* | | |
| GM biotechnology | 0.80*** (0.14) | 1.28***(0.13) |
| Large benefit | 0.23** (0.09) | 0.003 (0.33) |
| *Non-Random Parameters in Utility function* | | |
| ASC | 1.32*** (0.13) | |
| Medium bunch size | 0.40*** (0.03) | |
| Large bunch size | 0.60*** (0.04) | |
| Medium benefit | 0.13*** (0.03) | |
| Price (% change) | -0.02***(0.00) | |
| Log likelihood at start | -3421.65 | |
| Simulated log likelihood at convergence | -3378.28 | |
| Likelihood ratio test 86.7 ($\chi^2_{0.99}(13)$) = 27.7, McFadden $\rho^2$ = 0.314 | | N = 4496 |
| **Urban** | | |
| *Random Parameters in Utility function* | | |
| GM biotechnology | | 1.88***(0.22) |
| Large benefit | 0.84*** (0.22) | 0.07 (0.24) |
| | 0.04 (0.16) | |
| *Non-Random Parameters in Utility function* | | |
| ASC | 0.99*** (0.16) | |
| Medium bunch size | 0.59*** (0.05) | |
| Large bunch size | 0.78*** (0.07) | |
| Medium benefit | 0.13*** (0.05) | |
| Price (% change) | -0.02*** (0.00) | |
| Log likelihood at start | -1908.76 | |
| Simulated log likelihood at convergence | -1850.72 | |
| Likelihood ratio test 116.1 ($\chi^2_{0.99}(13)$) = 27.7, McFadden's $\rho^2$ = 0.244 | | N = 2240 |

Notes: standard errors in parentheses. *denotes significance at the 10 percent level, **significance at the 5 percent level, and ***significance at the 1 percent level. Replications for simulated probability were 500.

constant across the population. Second, if the mean coefficient is zero (or significantly smaller than the standard deviation) with a significant estimated standard deviation, this indicates that there is preference diversity, i.e., both positive and negative. Third, if both the mean coefficient and estimated standard deviation are insignificant, then the attribute has no impact on choices.

As hypothesized in the survey design and supported by the descriptive statistics, consumers in the two locations are likely to value banana attributes differently. To test this heterogeneity, the Swait-Louviere log-likelihood ratio test was conducted and the null hypothesis that the separate effects of locations are equal to zero was rejected at the one percent significance level. Hence, consumers in the two locations have distinct preferences for banana attributes and their preferences cannot be pooled together.

The overall fit of the models (McFadden's $\rho^2$), pooled, rural and urban, are relatively high.[6] There is substantial preference heterogeneity in consumers' valuation of GM biotechnology attribute, as evidenced by statistically significant standard deviations for all samples. The standard deviation on the GM biotechnology is large for all samples, implying that some consumers in the sample prefer GM banana and others do not. According to the normal calculator, all other factors held equal, in the pooled sample 28 percent would not prefer GM banana (i.e., prefer traditional banana) and close to three quarters (72 percent) would prefer GM bananas. In the split samples, the preferences for GM biotechnology are also skewed to the positive side, with 73 percent and 67 percent of the consumers preferring GM biotechnology in the rural and urban areas, respectively. That is, 27 percent of consumers in rural areas and 33 percent in urban areas do not prefer GM biotechnology. However, the standard deviation for the large benefit for producers attribute is not significant, which implies that the preference parameter is constant across the population.

### 4.4.2 Random parameter logit model with interactions

Boxall and Adamowicz (2002) comment that even if the unobserved heterogeneity can be accounted for in the RPLM; the model fails to explain the *sources* of heterogeneity. That is,

[6] The $\rho^2$ value in conditional logit models is similar to the $R^2$ in conventional analysis except that significance occurs at lower levels. Hensher et al. (2005, p. 338) comment that values of $\rho^2$ between 0.2 and 0.4 are considered to be extremely good fits, similar to values between 0.7 and 0.9 for the $R^2$ in case of the ordinary least square.

the model predicts the population that may like or dislike a given banana bunch attribute, but provides no information as to who is in this group. In order to identify the possible sources of heterogeneity, interactions of respondent-specific social and economic characteristics with choice specific attributes were included in the utility function. Respondent-specific social and economic characteristics to be included in the models were selected after testing for correlations and multi-collinearity problems using correlation matrices and calculating Variance Inflation Factors (*VIF*) for each variable respectively. *VIF* were calculated by running 'artificial' ordinary least squares regressions between each of the independent variable as the 'dependent' variable with other remaining independent variables.[7] Independent variables which exhibited *VIF* > 5 are eliminated, indicating that they are affected by multi-collinearity (Maddala 2001).

Based on the correlation matrices and *VIF* results, seven consumer characteristics were retained and interacted with the five banana attributes levels in order to investigate the possible sources of heterogeneity. The selected consumer characteristics included: (i) household size (HHSIZE); (ii) whether or not the respondent had post-secondary education (EDUC); (iii) log of household monthly income (INCOME); (iv) age of the respondent (AGE); (v) whether or not the household grows banana (GROW); (vi) whether or not the household was found in the Eastern Region (EAST); and (vii) whether or not the household was found in the Southwestern Region (SWEST).

Equation 4.7 was then extended to include the 42 interactions between the six banana bunch attributes and the seven respondent-specific characteristics:

$$\begin{aligned} V_{ij} &= \beta + \beta_1(Z_{BUNMED}) + \beta_2(Z_{BUNLAR}) + \beta_3(Z_{BENMED}) + \beta_4(Z_{BENLAR}) \\ &+ \beta_5(Z_{GMTEC}) + \beta_6(Z_{PRICE}) + \delta_1(Z_{BUNMED} * S_{HHSIZE}) + \delta_2(Z_{BUNLAR} * S_{HHSIZE}) \\ &+ \ldots + \delta_{42}(Z_{PRICE} * S_{SWEST}) \end{aligned} \tag{4.7'}$$

The RPLM with interactions for both rural and urban samples were estimated using LIMDEP

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[7] *VIF* for each regression are calculated as: $VIF = \frac{1}{1\text{-}R^2}$, where $R^2$ is the $R^2$ of the artificial regression with the $i^{th}$ independent variable as a 'dependent' variable.

9.0 NLOGIT 4.0. Interactions that are significant at 10 percent level and less are reported in Table 4.4.

Compared to the RPLM, the RPLM with interactions exhibit a higher level of parametric fit, with $\rho^2$ of 0.33 for rural and 0.28 for urban samples. The Swait-Louviere log likelihood ratio test is used to compare the RPLM against the RPLM with interactions and the null hypotheses that the regression parameters for RPLM and the RPLM with interactions are equal is rejected at the one percent significance level, indicating that improvement in the models is achieved with the inclusion of social and economic characteristics.

The results for RPLM with interactions reveal that the standard deviations for both the GM biotechnology and large benefit for producers are significant for the rural sample (unlike the RPLM results), whereas only the standard deviation of the GM biotechnology is significant for the urban sample, indicating that data maintains choice specific unconditional unobserved preference heterogeneity for this attribute. However, the ranking and magnitude of the coefficient on the large benefit attribute differ across the two locations, revealing that this attribute causes disutility among urban consumers compared to rural ones. The significant standard deviation for large benefit for the rural sample indicates that 25 percent of all households in rural areas do not prefer large benefits for producers. The reason could be that some of the rural consumers perceived GM biotechnology products to be risky, which in turn could influence their choice for large benefits for producers. This is a surprising result and needs more explanation. One would expect this either to be zero or positive. A careful elaboration of these results is something that might be useful for future research. In addition, all the utility coefficients for the banana attributes reported in Table 4.4, for both rural and urban samples, are significant determinants of banana bunch choice. The ASC is positive and significant for both rural and urban sub samples, suggesting that consumers prefer the change options over the status quo, i.e., they prefer the GM (disease-resistant) to traditional varieties.

The interactions between higher education (EDUC) and attributes are all negative (Medium bunch*EDUC, Large benefit*EDUC, GM biotechnology*EDUC, and Large bunch size*EDUC), indicating a negative effect of higher education in particular towards GM biotechnology. Moreover, the interaction between GM biotechnology and age (AGE) is also negative. The results imply that respondents with higher education and those who are older are less likely to prefer improvement of bananas through GM biotechnology. In the rural areas,

**Table 4.4. RPLM with interactions.**

| | Rural consumers | | Urban consumers | |
|---|---|---|---|---|
| | Coeff. | Coeff. Std. | Coeff. | Coeff. Std. |
| *Random Parameters in Utility function* | | | | |
| GM biotechnology | 1.02***(0.20) | 1.27***(0.13) | 1.56***(0.29) | 1.75***(0.20) |
| Large benefit | 0.28***(0.10) | 0.41** (0.21) | -0.75* (0.41) | 0.06 (0.26) |
| *Non-Random Parameters in Utility function* | | | | |
| ASC | 1.34***(0.13) | | 1.02***(0.17) | |
| Medium bunch size | 0.24***(0.06) | | 0.65***(0.05) | |
| Large bunch size | 0.37***(0.08) | | 0.89***(0.07) | |
| Medium benefit | 0.13***(0.03) | | 0.13***(0.05) | |
| Price (% change) | -0.02***(0.00) | | -0.02***(0.00) | |
| Medium bunch size* EDUC | -0.18* (0.10) | | -0.27***(0.10) | |
| Medium bunch size *HHSIZE | 0.03***(0.01) | | | |
| Large bunch size* HHSIZE | 0.04***(0.01) | | | |
| Large bunch size* GROW | | | 0.64***(0.15) | |
| Large bunch size* EDUC | | | -0.54***(0.12) | |
| Large benefit*EDUC | -0.30**(0.12) | | | |
| Large benefit* INCOME | | | 0.15**(0.07) | |
| GM biotechnology*EDUC | -0.40**(0.16) | | -1.10***(0.19) | |
| GM biotechnology*HHSIZE | 0.06***(0.01) | | -0.10***(0.02) | |
| GM biotechnology*AGE | -0.01***(0.00) | | | |
| GM biotechnology* EAST | 0.32***(0.11) | | -0.73***(0.16) | |
| GM biotechnology*SWEST | -0.52***(0.10) | | | |
| Log likelihood at start | -3334.05 | | -1781.47 | |
| Simulated log likelihood | -3285.82 | N=4496 | -1729.13 | N=2240 |
| Likelihood ratio test | 96.5($\chi^2_{0.99}$(22)) = 40.3<br>McFadden's $\rho^2$ = 0.333 | | 104.7($\chi^2_{0.99}$(20)) = 37.6<br>McFadden's $\rho^2$ = 0.284 | |

Note: standard errors are in parentheses. * denotes significance at the 10 percent level, ** significance at the 5 percent level and *** significance at the 1 percent level. Replications for simulated probability were 500.

the positive and significant interactions between the two levels of bunch size and GM biotechnology and household size (HHSIZE) indicate that larger households are likely to pay more for improvement of banana bunches, notably through GM biotechnology. In the urban areas, however, larger households are less likely to prefer GM biotechnology. In addition, the interactions between large benefit for producers and income (INCOME) as well as between large bunch size and banana growers (GROW) are positive, indicating that banana-growers and higher income-earners are more likely to choose banana bunch attributes with such improvements. The interaction between the GM biotechnology attribute and Eastern Region (EAST) in the rural sample was positive whereas in urban areas it was negative, indicating the likely locational effects on the acceptance of GM banana. While, the negative interaction between the GM biotechnology attribute and the Southwestern Region (SWEST) in rural areas indicates that consumers (who are mainly banana-selling households (76 percent) particularly to urban markets) in this region are less likely to prefer GM bananas.

### 4.4.3 Estimation of Willingness to Pay

In order to capture the marginal utility of income, willingness to pay estimates are derived. The derived estimates denote the percentage change in price, which consumers are willing to pay as a premium (or discount) for each banana bunch attribute. That is, the implicit percentage price changes reflect WTP for a distinct change in the attribute's level, e.g. to improve benefits to producers from none (status quo) to medium or large. The marginal value of change in a single banana attribute can be represented as a ratio of coefficients, which represents the marginal rate of substitution between price and the banana attribute in question, or the marginal WTP in terms of a price premium or discount for a change in any of the attribute levels. This WTP is calculated as (cf. Louviere et al. 2000):

$$WTP = -\left(\frac{\beta_{attribute}}{\beta_{price}}\right) \tag{4.8}$$

The demand functions for the improvement in the banana bunch quality conditional on the consumer characteristics reported in Tables 4.5 can be used to calculate the value assigned by the household to banana attributes, by modifying equation (4.8).

$$WTP = \left[ \frac{\beta_{attribute} + \delta_{attribute*S_1} + \ldots + \delta_{attribute*S_7}}{\beta_{price} + \delta_{price*S_1} + \ldots + \delta_{price*S_7}} \right] \quad (4.8')$$

Variables $S_1$ to $S_7$ are the seven consumer specific characteristics under consideration.

Using the Wald Procedure (Delta method) in LIMDEP, consumers' valuation (WTP) of banana attributes are calculated for the average households in each location, and for three household profiles, defined in terms of income group (total monthly income) (Uganda Bureau of Statistics 2006c). These household profiles were generated to investigate if there is significant heterogeneity between different income groups' WTP for banana bunch attributes.

The first profile belongs to the low-income category with incomes less than or equal to Ugandan Shillings (UGX) 50,000, the second profile to middle-income category with monthly incomes between UGX 50,001 and 200,000, and the third profile to high-income category with average monthly incomes over UGX 200,000. The average characteristics of the three profiles are reported per location in Table 4.5.

**Table 4.5. Average socioeconomic characteristics of the three household profiles by location.**

| | Rural | | | Urban | | |
|---|---|---|---|---|---|---|
| | Low income | Middle income | High income | Low income | Middle income | High income |
| Monthly income | 23459.0 | 100480.0 | 488647.0 | 30474.0 | 115645.0 | 666026.0 |
| Age | 43.1 | 41.3 | 41.7 | 34.6 | 42.5 | 35.8 |
| Household size | 6.0 | 6.4 | 7.8 | 5.2 | 4.9 | 5.9 |
| Post-secondary education (%) | 3.0 | 4.6 | 15.0 | 10.3 | 6.2 | 31.7 |
| Grow banana (%) | 96.2 | 94.5 | 97.5 | 37.9 | 62.5 | 44.4 |

Table 4.6 shows the implicit prices, in percentages, calculated using equation 4.8' and the respective 95 percent confidence intervals, and calculated using the Wald procedure. The

implicit prices for all attributes were positive and significant, with exception of large benefit in urban areas where consumers were found to be indifferent. This implies that respondents have a positive WTP for improvement in the banana bunch quality from lower level (base case) to a medium or high level of improvement and from traditional varieties to genetically modified ones. Notice that for the two three-leveled attributes, bunch size and benefit for producers, implicit prices rise as the extent of improvement over the base category increases—with the exception of the large benefit in urban areas.

In order to assess whether there are significant differences between the WTP values of the three profiles that exhibited significant WTP values for banana bunch attributes, a Poe et al. (1994) simple convolutions process was undertaken (Rolfe and Windle, 2005). After having calculated the WTP, differences between WTP values were calculated by taking one vector of WTP from another. The 95 percent confidence interval is approximated by identifying the proportion of differences that are different from zero. These results are reported in Table 4.7.

The results reveal that WTP values differ significantly at 5 percent level between at least one pair of the household profiles for all choice attributes (Table 4.7). In the rural areas, significant differences for medium bunch size were only seen among low and medium-income household profiles. But for large bunch size attribute households valued the attribute differently, with high-income earners willing to pay the highest, followed by medium-income earners. In the urban areas, both medium and large bunch sizes are valued differently across the three household profiles. That is, the middle-income households are willing to pay the highest for both medium and large bunch sizes, followed by low-income ones. The reason could be that banana is the main source of carbohydrates for middle income households, whereas other sources rather than banana could be afforded by the wealthier households. No significant differences were recorded for consumers' WTP for medium benefit for farmers, implying that the attributes level was valued similarly across the three household profiles within both rural and urban areas. For large benefit, consumers valued the attribute somewhat differently in rural areas, with poorer households willing to pay the highest for larger benefits, followed by middle income earners. While in urban areas, the large benefit attribute was similarly valued across the three profiles. There is, however, significant heterogeneity regarding consumer demand for GM biotechnology attribute between the low-income earners

**Table 4.6. Household profiles' WTP for banana bunch attributes by location as percent change in price (95 percent Confidence Interval).**

| Attribute levels | Location Average | Low income | Medium income | High income |
|---|---|---|---|---|
| **Rural** | | | | |
| Medium bunch size | 21.2<br>(19.3, 23.1) | 20.7<br>(18.8, 22.6) | 21.2<br>(19.3, 23.1) | 22.4<br>(20.3, 24.5) |
| Large bunch size | 30.7<br>(28.0, 33.4) | 29.9<br>(27.2, 32.6) | 30.7<br>(28.0, 33.4) | 33.3<br>(30.3, 36.2) |
| Medium benefit | 6.4<br>(4.8, 8.1) | 6.4<br>(4.8, 8.1) | 6.4<br>(4.8, 8.1) | 6.4<br>(4.8, 8.1) |
| Large benefit | 12.9<br>(8.2, 17.6) | 13.2<br>(8.5, 18.0) | 13.0<br>(8.3, 17.7) | 11.5<br>(6.8, 16.2) |
| GM technology | 35.6<br>(26.5, 44.7) | 42.4<br>(35.8, 49.0) | 40.6<br>(34.0, 47.1) | 42.3<br>(35.5, 49.0) |
| **Urban** | | | | |
| Medium bunch size | 25.8<br>(23.0, 28.6) | 26.8<br>(24.8, 28.8) | 27.3<br>(24.3, 30.2) | 24.3<br>(21.5, 27.0) |
| Large bunch size | 33.8<br>(30.3, 37.3) | 35.7<br>(32.1, 39.4) | 36.7<br>(32.9, 40.4) | 30.8<br>(27.4, 34.2) |
| Medium benefit | 5.8<br>(3.6, 7.9) | 5.8<br>(3.6, 7.9) | 5.8<br>(3.6, 7.9) | 5.8<br>(3.6, 7.9) |
| Large benefit | - | - | - | - |
| GM technology | 39.2<br>(30.2, 48.3) | 39.1<br>(29.9, 48.2) | 48.7<br>(39.0, 58.5) | 32.1<br>(23.4, 40.7) |

Note: - indicates not significant at the 10 percent level or better.

and medium-income earners in rural areas. The poorer households have a significantly higher WTP for GM bananas compared to middle-income households. This could be because poorer households' incomes are less diversified and depend more on banana than middle income households. While in urban areas, GM biotechnology is valued differently across the three profiles, with the medium-income earners willing to pay the highest, followed by the poorer households, whereas wealthiest are willing to pay least. The results, therefore, confirm the presence of significant heterogeneity for WTP for these attributes within the sampled population.

**Table 4.7. Proportion of banana bunch attribute value estimates different than zero.**

| | Rural | | | Urban | | |
|---|---|---|---|---|---|---|
| Attribute levels | Low income vs. Medium income | Low income vs. High income | Medium income vs. High income | Low income vs. Medium income | Low income vs. High income | Medium income vs. High income |
| Medium bunch size | 0.9905** | 0.9227 | 0.9109 | 0.9918** | 0.9918** | 0.9918** |
| Large bunch size | 0.9998** | 0.9998** | 0.9998** | 0.9999** | 0.9999** | 0.9993** |
| Medium benefit | 0 | 0 | 0 | 0 | 0 | 0 |
| Large benefit | 0.9819** | 0.9819** | 0.9819** | - | - | - |
| GM technology | 0.9676** | 0.0500 | 0.8408 | 0.9999** | 0.9993** | 0.9999** |

Note. ** indicates significance at the 5 percent level or better.

## 4.5 Conclusions

This chapter investigated consumers' preferences heterogeneity for different banana attributes in Uganda. The analysis of the choice data took into consideration preference heterogeneity resulting from location specific and household level characteristics. Findings reveal that there is substantial conditional and unconditional heterogeneity, as accounted for by the random parameter logit models with interactions, carried out for each location (urban and rural) separately. There are considerable variations in the valuation of GM biotechnology and large benefit attributes among rural consumers, and GM biotechnology among urban consumers.

The impacts of social and economic characteristics of the consumers on their valuation of the banana bunch attributes were significant, indicating the importance of considering such characteristics in explaining the sources of conditional heterogeneity. It is interesting to note that urban and rural preferences differ towards the introduction of GM banana. The low-income rural households with larger household sizes value GM technology that generates large benefits to producers more highly than the urban ones. Conversely, the old consumers in rural areas as well as the highly educated ones in both rural and urban areas—who are more likely to be opinion leaders in their respective locations—were found to be more critical toward the GM technology and large benefits for producers, which would negatively influence their willingness to accept or adopt the GM banana.

It is important to understand societal responses toward modern biotechnology and its applications, since public support is crucial if a technology is to be accepted and adopted. It is necessary for the government to be aware of the possible rejection, which may require a careful strategy to introduce GM banana in Uganda.

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# Appendix

## Appendix 4A.1 Conditional logit model

Using LIMDEP 9.0 NLOGIT 4.0., we estimated the pool and separate conditional logit models (CLMs) and tested the null hypothesis that the separate effects of locations are equal to zero. The Swait Louviere log-likelihood ratio test rejects the null hypothesis that the separate effects are equal at one percent significant level. The results are presented in Table A4.1.

**Table 4A.1. CLM estimates for all samples, rural and urban.**

| Variable | Pooled | Rural | Urban |
|---|---|---|---|
| | Coefficient | | |
| ASC | 0.660(0.070)*** | 0.870***(0.090) | 0.380 (0.110) |
| Medium Bunch size | 0.330(0.020)*** | 0.290***(0.020) | 0.400*** (0.030) |
| Large bunch size | 0.450(0.020)*** | 0.430***(0.020) | 0.510***(0.040) |
| Medium benefit | 0.110(0.020)*** | 0.110***(0.030) | 0.100** (0.040) |
| Large benefit | 0.170(0.020)*** | 0.190***(0.030) | 0.130***(0.040) |
| GM biotechnology | 0.350(0.030)*** | 0.410***(0.040) | 0.240*** (0.050) |
| Price | -0.010(0.001)*** | -0.01***(0.001) | -0.010***(0.001) |
| Sample size | 6736.000 | 4496.000 | 2240.000 |
| McFadden's $\rho^2$ | 0.104 | 0.114 | 0.093 |
| Log likelihood | -5366.391 | -3421.653 | -1908.759 |
| Swait-Louviere likelihood ratio test 71.900 ($\chi^2_{0.99}$(7) = 18.500 | | | |

Notes: standard errors are in parentheses. * denotes significance at the 10 percent, ** at the 5 percent, and *** at the 1 percent levels.

To test whether the CLM is appropriate, the Hausman and McFadden (1984) test for the IIA property was conducted for the CLM regressions for each location. The results of the test for each location and pooled are reported in Table A4.2. The property of the IIA is significantly violated at 1 percent level when at least one of the three choice options is dropped, indicating that the models do not completely conform to the underlying IIA property. Therefore the CLM can be augmented by either employing the random parameter (mixed) logit model or by including social and economic respondent-specific characteristics as interactions or both (Revelt and Train 1998).

**Table 4A.2. Test of independence of irrelevant alternatives.**

| | Pooled | | | Rural | | | Urban | | |
|---|---|---|---|---|---|---|---|---|---|
| Alternative dropped | $\chi^2$ | df | Prob. | $\chi^2$ | df | Prob. | $\chi^2$ | df | Prob. |
| Scenario A | 1997.750 | 7 | 0.000 | - | | - | 592.110 | 7 | 0.000 |
| Scenario B | 170.210 | 7 | 0.000 | 81.200 | 7 | 0.000 | 81.390 | 7 | 0.000 |
| Scenario C | - | | - | - | | - | - | | - |

Note: – indicates that the model failed to converge. df denotes degree of freedom.

# Chapter 5

# A Latent Class Approach to Investigating Consumer Demand for Genetically Modified Staple Food in a Developing Country: the Case of GM Banana in Uganda♦

♦ This paper was published as Kikulwe, E., E. Birol, J. Wesseler, and J. Falck-Zepeda. 2009. A Latent Class Approach to Investigating Consumer Demand for Genetically Modified Staple Food in a Developing Country: the Case of GM Banana in Uganda. Discussion Paper no. 938. Washington, D.C: International Food Policy Research Institute. The paper was also presented at the 27th International Association of Agricultural Economists Conference, Beijing, China. A version of this paper is submitted to *Agricultural Economics.*

## 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 plants. 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 who are located in the rural areas of the Eastern Region. These food insecure households would benefit the most from the commercial release of GM bananas. In contrast, urban consumers are less accepting of GM bananas, and they would benefit less from their introduction. According to the 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 banana; consumers; choice experiment; latent class model; preference heterogeneity; Uganda

## 5.1 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 income, 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 the national researchers to adopt a long-term breeding strategy of using conventional and genetic modification (GM) methods to introduce resistance. However, the high-yielding varieties of cooking bananas proved to be sterile, slowing down their improvement through conventional breeding (Ssebuliba et al. 2006). Since such major biotic constraints are not easily addressed through conventional breeding and/or crop management practices, recent efforts have involved the use of the GM methods to insert resistance traits into selected banana planting material. Unlike conventional breeding, GM 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 (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 banana varieties. We examine how consumers in a developing country with varied or scanty 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 bunch 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.

When estimating preferences, heterogeneity of preferences in the sample should be accounted for with the use of the appropriate model. A number of alternative models have developed to account for heterogeneity, including the covariance heterogeneity (CovHet) model (Colombo, Hanley, and Louviere 2009), the random parameter logit model (RPLM) (Rigby and Burton 2005; Greene and Hensher 2003; McFadden and Train 2000; Train 1998), and the latent class model (Louviere et al. 2000; Swait 1994). Colombo, Hanley and Louviere (2009) provide a detailed comparison of these models of integrating and explaining preference heterogeneity in choice modeling.

This chapter 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 relative closeness to the European view towards GM food over 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 by comparing statistically significant different segments of the sample. Second, this study includes economic 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 5.3 describes the data. Econometric results are reported and discussed in Section 5.4. The last section draws conclusions and discusses policy implications.

## 5.2 Choice modeling approach

### 5.2.1 Theoretical framework

In the previous chapter (Chapter 4) we split the sample into rural and urban households to investigate differences between the two groups. But some of the households might form a group called segment based on their characteristics which does not depend on whether they are rural or urban. Those characteristics might be more important than the urban/rural characteristic and provide a different picture about household choices as segments may result including rural as well as urban households. Recent applications of the LCM for welfare assessment of a new technology such as GM food include e.g. Birol, Villalba, and Smale (2009), Kontoleon and Yabe (2006), and Hu et al. (2004).

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 describes a population as consisting of a finite and identifiable number of groups of individuals called segments. Preferences are relatively homogeneous within segments, but differ substantially across segments. The number of segments is determined endogenously by the data. The insertion of an individual into a specific segment is probabilistic, and depends on the characteristics of the respondents. In the model, 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 food items. For example, Ruto, Garrod, and Scarpa (2008), Ouma, Abdulai, and Drucker (2007), and Scarpa et al. (2003) employed this model for the valuation of livestock attributes; Kontoleon and Yabe (2006), Owen et al. (2005), and Hu et al. (2004) used it to investigate consumer preferences for GM food; and Birol, Villalba, 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:

$$U_{ij/s} = \beta_s X_{ij} + \varepsilon_{ij/s} \tag{5.1}$$

where $X_{ij}$ is a vector of attributes associated with banana bunch alternative *j* of a choice set *C* and consumer *i,* and $\beta_s$ is a segment-specific vector of taste parameters. The differences in $\beta_s$ 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 distribution, the probability $P_{ij/s}$ of alternative *j* being chosen by the *i*th individual in segment *s* is then given by:

$$P_{ij/s} = \frac{\exp(\beta_s X_{ij})}{\sum_{h=1}^{C} \exp(\beta_s X_{ih})} \tag{5.2}$$

A membership likelihood function M* is introduced to classify 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, $\lambda_k (k = 1,2,...S)$ the segment-specific parameters to be estimated and $\xi_{is}$ the error term. Assuming that the error terms in the consumer membership likelihood function are IID across consumers and segments, and follow a Type 1 distribution, the probability that consumer *i* belongs to segment *s* can be expressed as:

$$P_{is} = \frac{\exp(\lambda_s Z_i)}{\sum_{k=1}^{S} (\lambda_k Z_i)}. \tag{5.3}$$

The segment specific parameters $\lambda_k$ denotes the contributions of the various consumer characteristics to the probability of segment membership $P_{is}$. A positive (negative) and significant $\lambda$ 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 $0 \leq P_{is} \leq 1$.

By bringing equations 5.2 and 5.3 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:

$$P_{ijs} = (P_{ij/s}) * (P_{is}) = \left[ \frac{\exp(\beta_s X_{ij})}{\sum_{h=1}^{C} \exp(\beta_s X_{ih})} \right] \left[ \frac{\exp(\lambda_s Z_i)}{\sum_{k=1}^{S} \exp(\lambda_k Z_i)} \right]. \quad (5.4)$$

### 5.2.2 Choice experiment design

The first step in CE design is defining of 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 5.1.

The first attribute, bunch size, represents the average size of a banana bunch at the time of sales, and varies from small (5 to 15 kg) to large (over 25 kg). The majority of the banana bunches currently sold (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 estimated 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. Bergmann, Colombo, and Hanley 2008; Bergmann, Hanley, and Wright 2006; Othman, Bennett, and Blamey 2004). 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 (as well, see section 5.3.1). Therefore, we would expect that respondents would derive positive values from this attribute, whether due to altruistic reasons or self-interest.

**Table 5.1. Attributes, their definitions, levels and coding.**

| Attribute | Definition | Levels | Coded using |
|---|---|---|---|
| Bunch size | The average size of a banana bunch at harvest | Small<br>Medium<br>Large | Dummy variables |
| Benefit | The magnitude of the expected increase in the incomes of banana producers | none<br>medium<br>large | Dummy variables |
| Biotechnology | The type of biotechnology used to produce the banana planting material | Traditional<br>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 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 to eliminate diseases, while modern biotechnology involve the use of GM techniques auch as DNA diagnostic probes, recombinant DNA, functional and structural genomics, and other methods for genetic modification (Falck-Zepeda 2009). Currently, most banana-producing households in Uganda grow local cultivars of the 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].

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 discount based on the other attributes, i.e., the bunch size, the magnitude of the benefit, and the type of biotechnology. We use percentage change in prices because the price of banana bunches traded 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 Johnson et al. 2007; Kuhfeld 2004; Louviere et al. 2000) were used to structure the presentation of the attribute levels within choice sets. Following Johnson et al. (2007) and Kuhfeld (2004), a D-Optimal experimental design was constructed with only the main effects (using the SAS software). A fraction of a 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 5.1). The first three qualitative attributes (bunch size, magnitude of the 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,

[1] The utilized survey materials are provided in the annex to the main document.

therefore, the alternative specific constant (ASC) equaled 1 if either option A or B was chosen, and 0 if the respondent chooses 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. We expect positive utility for benefit and GM banana attribute levels based on altruistic reasons and more benefits through GM banana. GM banana variety always generates some benefits over local varieties.

## 5.3 Data

### 5.3.1 Study sites and sample characteristics

The target population included households residing in the Eastern Region, Central Region, and Southwestern Region 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 banana for both household consumption and sales 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 2006a). 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 selected 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 current community listing. 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. 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 5.2. Nearly half of the sampled households were located in the Central Region, while the Eastern Region and the Southwestern Region shared the rest of the sample equally. Two-thirds of the sampled households were located in rural 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 all 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 the context of

**Table 5.2. Comparison of consumer characteristics and population statistics.**

| Characteristic | Sample statistics | Population statistics[a] |
|---|---|---|
| | 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 | 5.2 |
| | (3.3) | |
| Total monthly household income (UGX)[b] | 194748.8 | 170891.0 |
| | (351179.0) | |
| | 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 household heads 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 |

Source. [a]UBOS 2006c.

Note: numbers in parentheses are standard deviations. [b] The exchange rate between July and August 2007 was US $1 = UGX 1750.

banana consumption. Roughly 60 percent of the sampled households bought bananas; of them approximately half (49 percent) purchased from the market to supplement their production. 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 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 2006c) 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.

### 5.3.2 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 3.1, chapter 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 various 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 banana.

In contrast, higher positive values for FKAPI and HKAPI indicate higher levels of concern over food-environment safety and health risks, respectively. A detailed description of factor analysis is reported in chapter 3.

## 5.4 Results

### 5.4.1 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 is estimated with two, three, four, and five segments. The log likelihood, $\rho^2$, Bozdogan Akaike Information Criterion (AIC3) and Bayesian Information Criterion (BIC) statistics for the models are reported in Table 5.3.

**Table 5.3. Criteria for determining the optimal number of segments.**

| Number of segments | Number of parameters (P) | Log likelihood (LL) | $\rho^2$ | AIC3 | BIC |
|---|---|---|---|---|---|
| 1 | 7 | -5366.391 | 0.273 | 10753.782 | 5401.089 |
| 2 | 19 | -4180.995 | 0.433 | 8418.990 | 4273.160 |
| 3 | 31 | -4180.995 | 0.433 | 8454.990 | 4331.370 |
| 4 | 43 | -4180.995 | 0.433 | 8490.990 | 4389.580 |
| 5 | 55 | -4180.995 | 0.433 | 8526.990 | 4447.789 |

Notes: the sample size is 6736 choices from 421 consumers (N); $\rho^2$ 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 5.3 (Andrews and Currim 2003; Louviere et al. 2000; Wedel and Kamakura 2000). The log likelihood decreases (improves) and $\rho^2$ increases as more

[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 5.4. 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) |
| Medium bunch size | 0.35*** (0.02) | 0.57*** (0.11) |
| Large bunch size | 0.49*** (0.02) | 0.84*** (0.12) |
| Medium benefit | 0.13*** (0.02) | -0.32** (0.13) |
| Large benefit | 0.21*** (0.02) | -1.13*** (0.17) |
| GM biotechnology | 0.48*** (0.03) | -0.94*** (0.11) |
| Price | -0.01*** (0.00) | -0.02*** (0.00) |
| 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) | - |
| Grow banana | 1.02**(0.61) | - |
| Log likelihood | -4180.995 | |
| $\rho^2$ (Pseudo $R^2$) | 0.433 | |
| Sample size | 20208 | |

Notes: standard errors are in parentheses. * denotes significance at the 10 percent level, ** significance at the 5 percent level and *** significance at the 1 percent level.

segments are added; both leveling off after the second segment, indicating the presence of multiple segments in the sample. The BIC and AIC3 are minimized at segment two. Based on the four criteria the model with two segments was selected for this empirical application.

The results of the two-segment LCM are shown in table 5.4. The first panel of table 5.4 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 5.4, 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 larger 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 members of this segment prefer the status quo.

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 attribute for the 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 and do not 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.

### 5.4.2 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 5.5.

The *potential GM banana consumers* are located mainly in rural areas; moreover, significantly larger and smaller proportions of the households reside in the Eastern Region and the Southwestern Region, respectively, compared to the *potential 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 the two regions, as well as high population pressures, which both lead to inadequacies of the banana supply for rural areas of the Eastern Region and Central Region. 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 better supplies. As expected, respondents in the *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 may have inadequacies in banana supplies. Banana producing households, therefore, 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 large-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)

**Table 5.5. 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 | 46.28 |
| | (13.27) | (16.32) |
| Household size** | 6.42 | 5.67 |
| | (3.30) | (3.20) |
| Banana acreage (ha) | 0.46 | 0.44 |
| | (0.72) | (0.71) |
| Household monthly income in UGX[a]*** | 143280.00 | 266395.8 |
| | (251506.40) | (444362.20) |
| Benefit index (BKAPI)*** | 0.30 | -0.36 |
| | (0.50) | (1.11) |
| Food and environment index (FKAPI)** | -0.09 | 0.09 |
| | (0.89) | (0.80) |
| Health index (HKAPI)*** | -0.11 | 0.11 |
| | (0.81) | (0.89) |
| | Percent | |
| Location, urban =1*** | 15.51 | 57.95 |
| Gender, female=1 | 40.00 | 47.72 |
| Off-farm employment, Yes =1*** | 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 *** | 22.86 | 36.36 |
| College or university education*** | 5.71 | 15.34 |
| Grow banana*** | 93.06 | 62.50 |
| Self-sufficient, No =1*** | 66.94 | 47.72 |

Note: numbers in the parentheses are standard deviations**.** . * indicates significance between means and or distributions of segment 1 and segment 2 members at the 10 percent level, ** significance at the 5 percent level and *** significance at the 1 percent level. [a] the exchange rate between July and August 2007 was US $1 = UGX 1750.

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 in India 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. Lin et al. 2006; McCluskey et al. 2003), our results suggest that wealthier people who have non-agricultural incomes are more likely to not to want GM food.

### 5.4.3 Consumer valuation of banana bunch attributes

The marginal value of each banana bunch attribute represents the consumer's marginal willingness to pay a premium (positive WTP values) or discount (negative WTP values) for a given attribute. The marginal value can be derived from the parameter estimates shown in table 5.5 by using $W = -\beta_k / \beta_y$ , where $\beta_y$ is the marginal utility of income (i.e., the coefficient of the monetary attribute, in this study, it is the banana bunch price) and $\beta_k$ is the coefficient of the banana bunch attributes (i.e., size, type of biotechnology or benefits).

As shown in table 5.6, marginal value figures were estimated for both segments. The numerical results represent the percentage change in the price consumers were WTP as a premium (or 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 changes in the attributes, as indicated in table 5.6

**Table 5.6. 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 average (N=421) |
|---|---|---|---|
| Medium bunch size** | 31.1 (27.5, 35.1) | 37.7 (25.1, 57.6) | 33.8(26.5,44.5) |
| Large bunch size*** | 43.1 (38.7, 48.2) | 56.1 (39.7, 81.9) | 48.6(39.1, 62.3) |
| Medium benefit*** | 11.2 (8.5, 14.9) | -20.9 (-24.1, -15.9) | -2.3(-5.2, 1.5) |
| Large benefit*** | 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) |

Notes: numbers in parentheses are the 95 percent confidence intervals. Consumers' valuation of banana attributes were calculated with the Delta method of the Wald procedure contained within the LIMDEP 8.0 NLOGIT 3.0. Numbers represent the percentage change in total price per banana bunch. *denotes significance at the 10 percent level, ** significance at the 5 percent level and *** significance at the 1 percent level.

We see variation in the ranking of banana bunch attributes and their impact on consumer utility 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 willing to pay price premiums for discrete changes in the levels of attributes. *Potential GM banana consumers* derive the highest positive values from banana bunches that are large in size and arise from GM biotechnology (such bunches receive the highest price premiums compared to the other attribute/level combinations). In contrast, *GM banana opponents* derive positive value only from 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 need a price discount for GM biotechnology, as well as for benefits for producers (medium or large) to compensate for their loss in utility.

## 5.5 Conclusions and policy implications

Two distinct segments of banana consumers are 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 they 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 GM bananas offering tangible benefits, such as pests and disease resistance and correspondingly higher yields, would likely be accepted by this segment representing about 58 percent of the sampled population. 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 clients 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 approximately 42 percent of 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 Region and Central Region, 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 the regulators 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 or support campaigns against the introduction of GM banana. 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. The *potential GM banana opponent* segment is the economically better off and better educated part of the population and mainly urban. Nevertheless, a large proportion of the segment is also from rural areas. Our findings generalize the argument by Paarlberg not only urban elites but also rural elites are more against the introduction of a GM banana. While Paarlberg has offered a convincing explanation for the negative attitudes of urban elites, it is less convincing for rural elites. Explaining the reason of the negative attitudes of rural elites towards GM banana needs further investigation. This aspect will be discussed in more details in the conclusion section in light of the results of the other chapters of the thesis.

According to the welfare estimates reported herein, both the total WTP among those who gain from the introduction of the GM technology (*potential GM banana consumers*) and the total WTA for those who lose as a result of the introduction of this technology (the *potential GM banana opponents*) are significant and large (Table 5.6). 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. (2008) and Bergmann et al. (2006), 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. 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 industrialized 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 social benefits it may generate for farmers.

Overall, our present 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 a GM banana in Uganda. Although this chapter 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 the associated benefits for producers. In particular the question if the observed disutility will be below or above the maximum incremental social tolerable irreversible costs (MISTICs) of GM bananas to identify if possible the benefits can compensate concerns of those who lose needs to be investigated further. This will be part of the subsequent chapter.

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# Chapter 6

## Introduction of a GM Banana and its Effects on Banana Producers and Consumers

## Abstract

GM crops and food are still controversial. This chapter integrates different approaches to investigate the effects of introducing a GM banana on banana producers and consumers. Findings reveal that introducing a GM banana would be beneficial for the Ugandan society as a whole. If the biosafety regulators are to address the concerns of the *potential GM banana opponents*, those additional costs may not exceed the foregone annual potential benefit ranging between US$ 179 to 365 million.


Keywords: GM banana, MISTICs, WTP, welfare measure, Uganda.

## 6.1 Introduction

The findings derived from the empirical analyses of the GM banana case as presented in chapters 2, 4 and 5 are crucial to the welfare measures in this chapter. First, the average annual maximum incremental social tolerable irreversible costs (MISTICs) per household calculated in chapter 2 were between approximately US$ 34 and US$ 69. These MISTICs were presented for different risk-free and risk-adjusted rates of return. At a risk-adjusted rate of return of 12 percent and a risk-free rate of interest of 4 percent, considered to be reasonable based on literature, the annual MISTICs per household and year were about US$38. This implies that only if the average household is willing to give up more than US$ 38 annually for not having GM bananas introduced postponing introduction may be considered. If postponed, the country will forego the potential benefits in the approximate range of US$179 million to US$365 million per year. In the fourth chapter the empirical results show that urban and rural households preferences differ significantly, with rural households, particularly poorer ones, willing to pay a significantly higher amount for a GM banana that generate large benefits to producers than urban households. This relates directly to the findings in chapter 5 that GM banana is valued the most by poorer households who are located in the rural areas of the Eastern Region. These households producing and buying banana would benefit the most from the commercial release of GM bananas. However, the utility of the segment mainly representing urban consumers decreases with the introduction of GM banana. These urban households who are mostly sole consumers (i.e., do not produce banana) are more concerned about potential risks of the technology compared to social benefits it may generate for producers.

In this chapter, these empirical findings are integrated in an economic welfare analysis to provide an overall assessment of the effects of introducing GM bananas on banana producers and consumers in Uganda. The MISTICs associated with the immediate introduction of a GM banana are compared with the estimated total willingness to pay (WTP) values for the GM banana under different scenarios. MISTICs are calculated while keeping in mind that the public is concerned about the not-so-well-known irreversible costs of the technology, such as negative effects on human health and the environment. The MISTICs indicate how much the society in general can tolerate as compensation for the benefits of the technology. If the perceived health and environmental risks of a safe banana exceed the estimated MISTICs, the society would not benefit from the GM banana introduction. Likewise, MISTICs can be interpreted as the maximum WTP for not having the GM banana approved for planting in the country (i.e. for the society as a whole). The WTP shows how much money consumers are willing to pay for or to avoid the introduction of a GM banana. An advantage of estimating the WTP is that the results of the study allows identification of the differences between segments of producers and consumers that can help to formulate national policies. Therefore, if the consumers' WTP for not having a GM banana introduced is greater than the MISTICs, i.e., the maximum WTP, then arguments can be advanced for delaying the introduction of the GM banana. If the WTP for not having a GM banana is positive but below the MISTICs, then very good economic arguments exist for not further delaying the introduction of the GM banana.

Even so we consider the GM banana to have passed the environmental and food safety assessment, Frewer et al. (2004) observe that much of the controversy associated with commercialization of genetically modified foods has been the failure of regulatory bodies to embrace the actual concerns of the public, which resulted into public distrust in motives of regulators, science, and industry. Public support is crucial if a technology is to be accepted and adopted by those who stand to benefit from it. In many Sub-Saharan African countries there is limited public participation in the debate on the impacts of GM crops and the role of modern biotechnology toward solving food insecurity (Clark, Mugabe, and Smith 2005). To ensure public acceptance for crop biotechnology and for designing enabling policies, consumer concerns need to be considered. In his paper, Saner (2007) spells out various reasons as to why the public need to be involved, which include: improving public policy, having a more informed and engaged public, supporting regulatory decisions, and creating public confidence in the government. To access the potential benefits of GM banana and other GM crops, therefore, Uganda would need to build public confidence in the technology and its implications towards poverty eradication. This chapter therefore focuses on the implications of introducing a GM banana given the public perceptions, positive as well as negative, toward the technology. We use simulations based on different combinations of impacts associated with GM banana introduction strategies. We hope that adequately analyzed economic welfare will shed light on the question under which conditions Uganda in particular, and African countries in general, will gain from GM crops without making a particular population segment worse off.

In what follows, section 6.2 provides a brief overview of the methodology. Section 6.3 presents the results of the welfare estimates and impacts towards GM banana introduction. The final section discusses the results and presents some conclusions.

## 6.2 Methodology

### 6.2.1 Compensation and WTP

According to the compensation principle, state B is preferred to state A if, the gainers can compensate the losers such that at least one person is better off and no one is worse off. If this is the case, a movement from state A to state B represents a *Pareto improvement* (Just, Hueth, and Schmitz (2004). Just, Hueth, and Schmitz cite the example of a tomato harvester. To determine whether a tomato harvester represents a potential Pareto improvement the maximum amount of money that gainers such as the producers, land owners, consumers, and machinery manufacturers are willing to pay for the harvester have to exceed the minimum amount of money that farm laborers would have to pay to tolerate the harvester.

In the case of introducing genetically modified foods, the compensating surplus is the commonly used WTP measure to test whether the proposed improvements is a Pareto improvement (Just, Hueth, and Schmitz 2004, pp. 417- 450). The compensating surplus (CS) is the amount of money which, when taken away from an individual after an economic change, leaves the person just as well off as before. In terms of welfare gain, it is the maximum amount that a person is willing to pay for the change. While for welfare losses, it is the negative of the minimum amount that a person would require as compensation for a change. In the context of GM banana, the welfare gain is the amount of money a consumer is willing to pay for the introduction of GM bananas, while welfare loss is the minimum amount of money a consumer must be paid, or is willing to accept as a compensation, to tolerate the introduction of GM bananas in the market. Several studies have employed the stated preference methods to estimate CS values and hence welfare impacts of policy changes. To test whether the introduction of GM banana is a Pareto improvement, we carry out a CS analysis in the sections that follow.

### 6.2.2 Model comparison

The objective of the choice experiment task and the associated model estimates in this study was to understand the economic impact of changing banana bunch attributes. Welfare measures refer to the amount that an individual is willing to pay in terms of price for banana bunch improvements. Different models were used to examine preference heterogeneity and to estimate consumers' willingness to pay for the various banana bunch attributes as reported in chapter 4 and 5. Models included: conditional logit model (CLM), random parameter logit model (RPLM) and RPLM with interactions and latent class model (LCM). Colombo, Hanley, and Louviere (2009) provide methods of comparing different approaches representing heterogeneity in stated choice modeling. In chapter 4, we conducted various statistical analyses using log-likelihood ratio tests to compare CLM, RPLM and RPLM with interactions. The result revealed that RPLM with interactions fit the data better.

As a starting point, therefore, in order to estimate the welfare measures and to derive policy implications, LCM is compared to the RPLM with interactions using the Ben-Akiva and Swait test (Ben-Akiva and Swait 1986). The test is done to determine whether preference heterogeneity can be explained either by the indirect effect of respondent-specific characteristics on banana attribute choice through membership segmentation or directly through the utility function (Kontoleon 2003). The test works as follows: first, we calculate the measure of fitness ( $\rho_j^2$ ) for each model:

$$\rho_j^2 = 1 - \frac{L_j - K_j}{L(0)} \tag{6.1}$$

where $L_j$ is the log likelihood at convergence for model $j$, $L(0)$ is the log likelihood assuming that choices are random and $K_j$ are the number of variables for each model.

Colombo, Hanley, and Louviere (2009) note that models may either have different functional forms, or the two sets of variables differ by at least one element. Assume that model 2 is more parsimonious that is, $K_1 \geq K_2$, then the null hypothesis will be that the more parsimonious model, the RPLM with interactions, is the 'true' specification for our data. The null hypothesis cannot be rejected if the following condition holds (Ben-Akiva and Swait

1986):

$$\Pr\left(\left|\rho_2^2 - \rho_1^2\right| \geq Z\right) \leq \Phi\left(-\sqrt{2ZL(0) + (K_1 - K_2)}\right) \tag{6.2}$$

where $Z$ is the difference of the fitness measures between model 1 and model 2 and is assumed to be greater than zero, and $\Phi$ is the standard normal cumulative distribution function.

A comparison between RPLM with interactions (rural sample) and LCM results into a probability of $P \leq \Phi(-37.20) \cong 0$ and that for RPLM with interactions (urban sample) and LCM gives a $P \leq \Phi(-26.55) \cong 0$.[1] This indicates that the null hypothesis is rejected; hence the LCM is preferred. These results reflect that the preference heterogeneity in our data is more accounted for at segment level rather than at individual level.

### 6.2.3 Compensating surplus welfare analysis

The best-fit latent class model (LCM), which is used to group the population into homogeneous segments, was employed to estimate the required parameters for welfare measures. The LCM allows us to calculate WTP welfare measures for each respondent within a segment. Deriving welfare measures under the LCM is done in two steps. First, policy impacts at the segment level are identified by calculating WTP welfare measures for each segment. Second, the standard aggregate procedure that assumes homogeneous preference is corrected for heterogeneity. That is done by computing the weighted sum of segment specific welfare measures. The weights are the estimated individual segment membership probabilities (Boxall and Adamowicz 2002). The individual segment WTP can finally be aggregated to calculate WTP welfare measures for the whole population.

The compensating surplus ($CS$) welfare measure for changes in the banana bunch attributes, conditional on the segment membership, can be derived from the estimated parameters by using the following equation (Bateman et al. 2003; Hanemann 1984):

---

[1]For RPLM with interactions for urban ($K_2$ = 16) and LCM ($K_1$ =19) $\rho_2^2 - \rho_1^2 = 0.198$, while for RPLM with interactions for rural ($K_2$ =18) and LCM $\rho_2^2 - \rho_1^2 = 0.207$.

$$CS_n = \frac{1}{\theta_{price}} \left[ \ln \sum_{i \in C} e^{V_i^1} - \ln \sum_{i \in C} e^{V_i^0} \right] \tag{6.3}$$

where the compensating surplus $CS_n$ is the amount of money that one would have to give the individual *n* after the change has occurred in order to remain as well off as before (i.e. after choosing alternative *i* in the choice set *C*); $\theta_{price}$ is the marginal utility of money and is the coefficient of the banana bunch price attribute; $V_i^0$ represents the individual's utility at the initial level (i.e., current state, banana bunches bred through traditional biotechnology); and $V_i^1$ is the utility of the alternative level (i.e., after change state, bunches bred by GM biotechnology) following changes in attributes.

The final marginal WTP welfare measure can be derived by, first, integrating the welfare effects across the different segments,

$$CS_{n|s} = \frac{1}{\theta_{price_s}} \left[ \ln \sum_{i \in C} e^{V_i^1} - \ln \sum_{i \in C} e^{V_i^0} \right] \tag{6.4}$$

where *s* = 1, 2; is the number of segments, and $\theta_{price_s}$ is the coefficient on the banana bunch price attribute for each segment providing each segment's marginal utility of income; and second, by calculating the weighted sum of the segment membership:

$$CS_{n|s}^t = \sum_{s=1}^{2} W_{ns} \left\{ \frac{1}{\theta_{price_s}} \left[ \ln \sum_{i \in C} e^{V_i^1} - \ln \sum_{i \in C} e^{V_i^0} \right] \right\} \tag{6.5}$$

where $W_{ns}$ is the probability of an individual $n$ being in segment $s$.

## 6.3 Results

### 6.3.1 Estimation of welfare measures

In order to estimate the consumers' compensating surplus (CS), conditional on being in segment one or two, for introduction of a GM banana over the status quo, four possible options were created. The creation of the four policy-relevant scenarios was based on the banana bunch profiles presented in Table 5.1 of chapter 5. The attribute levels that characterize a number of alternative banana bunch improvements scenarios are listed below, along with the base case:

- *Base case* (small bunches with no benefits)—status quo: this is the baseline situation where banana bunch consumed are mostly of small bunch sizes, produced through traditional biotechnology. The price for the base case is at UGX 3000 for a 10 kg bunch.
- *Scenario 1* (all medium improvement): medium banana bunch size produced by GM biotechnology and produced medium benefits (in form of increased yields) to producers.
- *Scenario 2* (all large improvement): large banana bunch size produced by GM biotechnology and generates large benefits to producers.
- *Scenario 3* (large bunch with medium benefits): large banana bunch size produced by GM biotechnology and generates medium benefits to producers.
- *Scenario 4* (medium bunch with large benefits): medium banana bunch size produced by GM biotechnology and generates large benefits to producers.

To find the CS associated with each of the above scenarios the difference between the welfare measures under status quo and the four banana bunch options are calculated. The estimated welfare changes (WTP) for the four scenarios are reported in Table 6.1.

Compensating surplus measures of welfare change are relatively high for segment 1, while, in all scenarios, willingness to pay is substantially lower for segment two. The CS estimates for the two segments differ significantly at the 95% confidence level. The *potential GM banana consumers'* households (segment one) obtain the largest CS from a GM banana with large bunches and large benefits for producers (scenario 2). The average CS gained per household in the first segment is between UGX 5542 and UGX 6112 per bunch. In contrast, the *potential GM banana opponents'* households (second segment) get their largest CS from a GM banana with large bunches and medium benefits for producers (scenario 3). The average CS obtained per household ranges between UGX 0.8 and UGX 2183 per bunch. In welfare terms the *potential GM banana opponents* are losing from the introduction of GM banana. Applying the compensation principle, they would need to get a compensation to tolerate the introduction of GM banana. When we consider the weighted total benefits, scenario 3 yields the highest CS. The weighted average shows improvement of welfare over the status quo (UGX 3000) for all scenarios, but there are losers and gainers when we look at each segment separately.

**Table 6.1. Compensating surplus and 95% confidence intervals for four bunch options.[a]**

| | Base case<br>Small bunch | Scenario 1<br>All medium improvement | Scenario 2<br>All large improvement | Scenario 3<br>Large bunch with medium producers benefits | Scenario 4<br>Medium bunch with large producer benefits |
|---|---|---|---|---|---|
| *Attribute levels* | | | | | |
| Bunch size | Small | Medium | Large | Large | Medium |
| Benefits | None | Medium | Large | Medium | Large |
| Biotechnology | Traditional | GM | GM | GM | GM |
| *Welfare(UGX)* | | | | | |
| Segment 1 | 3000 | 5542 | 6112 | 5905 | 5750 |
| (Gainers)[b] | | (5179, 5959) | (5707, 6577) | (5515, 6352) | (5370, 6185) |
| Segment 2 | 3000 | 1631 | 552 | 2183 | 0.8 |
| (Losers)[c] | | (1325, 2113) | (357, 857) | (1762, 2844) | (-79.6, 127.0) |
| Weighted average | 3000 | 3900 | 3777 | 4341.4 | 3335 |
| | | (3560, 4344) | (3460, 4175) | (3939, 4878) | (3081, 3335) |

Notes: numbers in parentheses are confidence intervals. [a] all figures are in UGX per bunch. [b] also refers to the *potential GM banana consumers* and [c] denotes the *potential GM banana opponents* as identified in chapter 5.

### 6.4.2 Comparison of CS for the potential GM banana opponents and MISTICs

In the previous section it was shown the *potential GM banana opponents* have negative WTP. The next step is to find out whether their negative WTP is below or above the MISTICs. We compare the MISTICs per bunch with the estimated total WTP per bunch. To calculate the MISTICs per bunch, we divide the annual MISTICs per household by the average number of bunches consumed per household. Using a per capita consumption of cooking banana in Uganda of 250 kg per annum (NARO 2001), an average bunch size of 10 kg (baseline), and an average household size of the *potential GM banana opponents* of 5.67 members per households (Table 5.5, chapter 5), and dividing the annual consumption with the average bunch size results in an average per capita consumption of 25 bunches per year. The product of the per capita bunches consumed and household size yields an average of approximately 142 bunches consumed per household per annum. Dividing the MISTICs per household by the bunches consumed per household and year and after deducting the planting costs provides the MISTICS per bunch presented in table 6.2.

**Table 6.2. MISTICs per household and MISTICs per bunch net of planting costs for the *potential GM banana opponents.***

| Risk-free rate of return (r) | MISTICs net of planting costs | Risk-adjusted discount rates ($\mu$) | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | 0.02 | 0.04 | 0.06 | 0.08 | 0.1 | 0.12 | 0.14 |
| 0.00 | MISTICs (UGX/household) | 89250.0 | 73500.0 | 61250.0 | 52500.0 | 45500.0 | 40250.0 | 36750.0 |
| | MISTICs (UGX/bunch) | 629.6 | 518.5 | 432.1 | 370.4 | 321.0 | 283.9 | 259.3 |
| 0.04 | MISTICs (UGX/household) | | 56000.0 | 59500.0 | 52500.0 | 45500.0 | 40250.0 | 36750.0 |
| | MISTICs (UGX/bunch) | | 395.1 | 419.7 | 370.4 | 321.9 | 283.9 | 259.3 |
| 0.10 | MISTICs (UGX/household) | | | | | 40250.0 | 40250.0 | 36750.0 |
| | MISTICs (UGX/bunch) | | | | | 283.9 | 283.9 | 259.3 |

Note: exchange rate by July 2007 was US$1 = UGX1750.

The results show the MISTICs to be between approximately UGX 630 (US$ 0.36) and UGX 259 (US$ 0.15) per bunch. As previously indicated, the MISTICs are the threshold values below which the irreversible costs have to be for the GM banana to be economically important to the *potential GM banana opponents*. In this case MISTICs are extremely small, i.e., less than one US dollar.

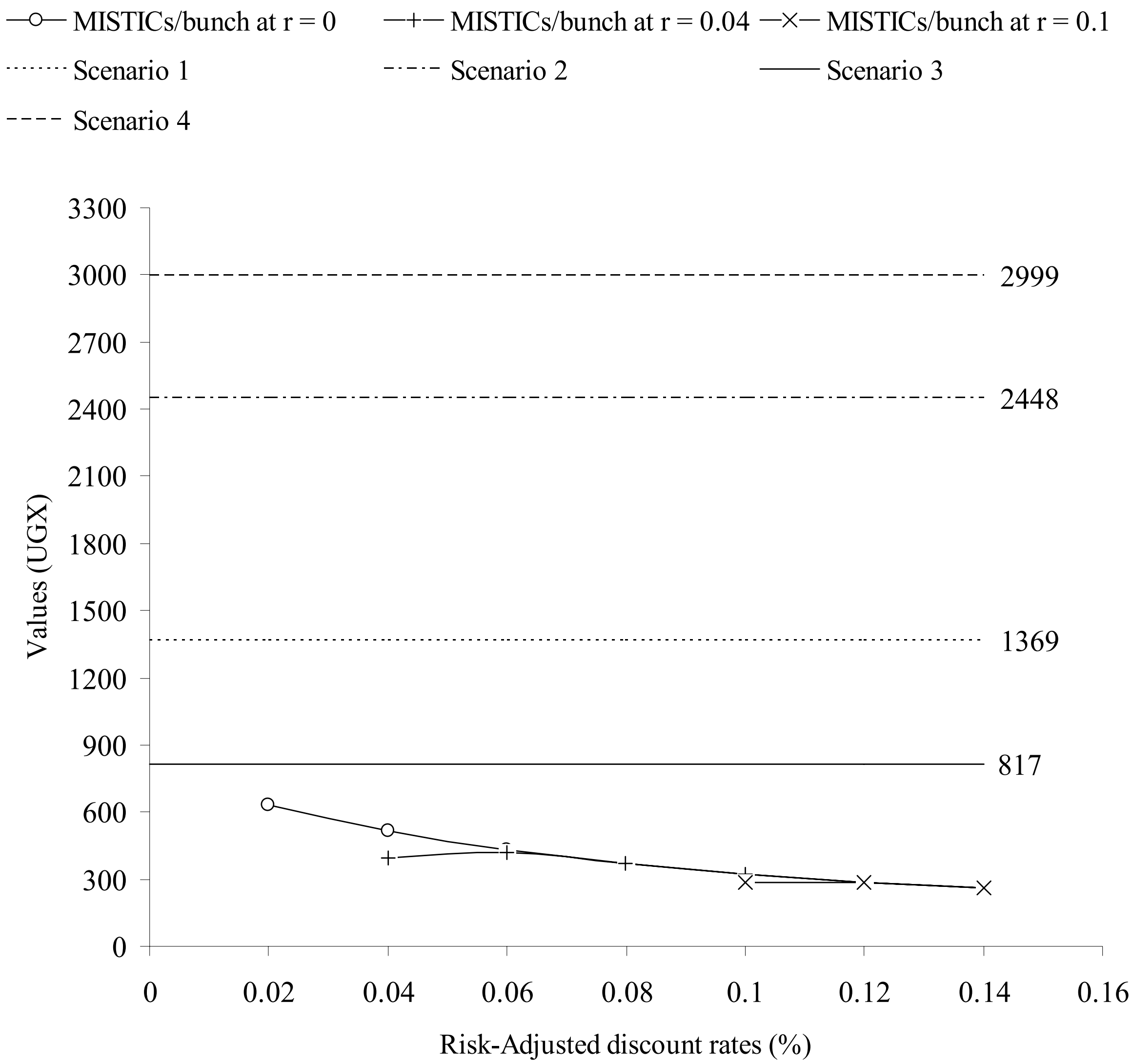


**Figure 6.1. Welfare and MISTICs per bunch at different risk-adjusted discount rates.**

If we compare MISTICs with the estimated total WTP for the proposed banana bunch improvements results show the MISTICs are far below the total WTP for the *potential GM banana opponents* (Fig. 6.1). Taking into account the MISTICs to be below the WTP, one may consider postponing the release of GM banana until the concerns for the *potential GM banana opponents* are resolved. But at aggregate level in table 6.1, results show improvements in welfare for all scenarios.

## 6.4 Discussion and conclusion

The aim of this chapter was to investigate the effects of introducing a GM banana on banana producers and consumers given the different alternative banana bunch improvement scenarios. The best-fit latent class model which enabled a representation of heterogeneity in the consumers' preferences at the segment level was chosen based on statistical grounds to compare with the MISTICs and draw some conclusions. Results show that there are gainers (the *potential GM banana consumers*) and losers (the *potential GM banana opponents*) in our sample, of which the total welfare for those who gain is greater than the total welfare for those who lose. According to the Hicksian WTP compensation criterion, our results suggest that the *potential GM banana consumers* who are mostly rural consumers can potentially compensate the *potential GM banana opponents* who are dominated by urban consumers in case a GM banana is to be introduced in Uganda. In other words, if a safe GM banana is to be introduced, our findings show that there is a population segment which might not benefit from its introduction. These findings confirm the need to take account of who gains and who loses from introducing a genetically modified banana and when devising strategies and policies for its dissemination and marketing.

The welfare changes associated with the four alternative scenarios confirm the differences in preferences between the *potential GM banana consumers* and the *potential GM banana opponents*. The *potential GM banana opponents* showed negative willingness to pay for all proposed GM banana improvements, while the *potential GM banana consumers* acknowledged much higher willingness to pay for all the proposed GM banana options. The GM banana, which is characterized by large bunches and large benefits to producers, was given the highest willingness to pay, especially when compared to the second best option, the GM banana with large bunches and medium benefits to producers. Rural respondents valued the more GM bananas which provide more benefits to their fellow farmers. The results are similar to those observed by Bergmann, Colombo, and Hanley 2008 that in Scotland rural respondents valued the more projects that improve job opportunities in their setting. Thus, a technology that can improve banana productivity of rural subsistence farmers, and hence increase their incomes would be highly acceptable by the rural households.

A comparison between the total willingness to pay for *the potential GM banana opponents* with the MISTICs show that all their negative WTP values are above the MISTICs. This result indicates the *potential GM banana opponents* are willing to give up more than the threshold value (maximum WTP for not having the GM banana introduced in Uganda). On the other hand, however, the estimated MISTICs per bunch for the *potential GM banana opponents'* households were very small, ranging from US$ 15 cents to US$ 36 cents. This imply that if the biosafety regulators are to address the concerns of the *potential GM banana opponents*, those additional costs may not exceed the potential benefit ranging between US$ 179 to 365 million per year (as estimated in chapter 2). Furthermore, for all scenarios welfare improves over the status quo. This implies that the introduction of a GM banana would be beneficial for all Ugandans. Nevertheless, if such a GM banana is introduced its introduction may result in strong opposition from the loser segment of the population, which is composed of mainly urban consumers. The implication is that the choice of the GM banana to benefit the whole society would depend on the cost of reducing opposition, which needs further investigation.

The findings of our study hold some implications for the government's mission towards poverty eradication through transforming subsistence agriculture to commercial agriculture. One of the government's objectives, through its Plan for Modernization of Agriculture (PMA), is to increase incomes and improve the quality of life of poor subsistence farmers through increased productivity and increased share of marketed production. In so doing, modern biotechnology was selected as one of the priority areas in its PMA (Oxford Policy Management (OPM) 2005). But GM crops are expected to have differing implications towards poverty eradication, depending on how the government supports the technology. The net social costs or benefits of most GM crops are likely to be crop-specific, especially in terms of food and environmental safety issues. Introduction strategies would need to consider the distribution of potential costs, benefits and risks associated with these new GM crops before a decision to introduce is made. From that perspective, if a GM banana is proved to be safe, findings have shown socioeconomic considerations are essential and care must be taken prior to its introduction. The negative risk perceptions among a given population segment as reported in this study would need to be off-set before its introduction. One way of off-setting the negative perceptions is to introduce compensation or benefit transfer method. Compensation can be done by providing more information about the safety of the technology through information campaigns. This in turn would improve knowledge dissemination channels. Likewise, other risk management instruments such as insurance or government compensation programs may merit discussion.

# Chapter 7

## General Discussion[♦]

♦ A revised version of this chapter has been accepted for publication as: Kikulwe, E; Birol, E., Wesseler, J., and J. Falck-Zepeda. (*forthcoming*, 2010). Consumer perceptions of the potential introduction of a fungal resistant banana in Uganda. In Falck-Zepeda, J., Gruere, G., and I. Sithole-Niang, (eds.) *Genetically modified crops in Sub-Saharan Africa: Lessons from economic and policy research*. Washington, D.C.: International Food Policy Research Institute.

## 7.1 Introduction

Banana is one of the staple crops in Uganda. Ugandans have the highest per capita consumption of cooking banana in the world (Clarke, 2003). However, banana production in Uganda is limited by several productivity constraints such as pests, diseases, soil depletion, and poor agronomic practices. In the mid 1990s, Uganda launched its long-term approach of breeding for resistance to banana (*Musa* spp.) productivity constraints using conventional breeding and genetic engineering methods. Through genetic engineering, the strategy is to develop genetically modified (GM) cultivars that are resistant to local pests and diseases, have improved agronomic attributes, and are acceptable to consumers (Kikulwe et al. 2007). The genetic engineering projects in Uganda have targeted the most popular and infertile cultivars that cannot be improved through conventional breeding.

Introducing a disease free GM banana variety is expected to provide both immediate and future benefits through the positive effects on yield, product quality, production costs and/or other crop characteristics, which would improve the livelihood of the poor subsistence farmers. The net-economic benefits of introducing GM banana depend on the reversible and irreversible benefits and costs the technology will generate. Currently, fungal resistant GM bananas are still undergoing biosafety field assessments. There are also a number of other GM bananas awaiting regulatory approval of the country's National Biosafety Committee for confined field trials (Kiggundu et al. 2008). After a thorough confined field testing, GM bananas are expected to be released into the environment for commercialization.

However, little is known about producer and consumer perceptions toward the technology in Uganda. Yet the introduction of GM banana in Uganda is likely to generate a wide range of concerns, as it has in other African countries. It is well known that concerns about compliance with biosafety regulations, environmental standards and food safety of GM organisms can be an important impediment to public acceptance of biotechnology products (Paarlberg 2008). The major objective of this thesis is to illustrate the relevance of socioeconomic analyses for supporting biotechnology decision-making and in particular the importance of consumer perceptions but also for contributing to the development and implementation of biosafety regulations.

I present a general approach using GM banana as an example, while assuming the GM banana has passed standard food and biosafety safety assessments, i.e. can be considered to be safe. The issues addressed in this research were: (i) the potential social incremental benefits and costs under effects of irreversibility, flexibility and uncertainty of introducing GM bananas in Uganda; (ii) the consumers' knowledge, attitudes and perceptions (KAP), and their implications for introducing GM bananas in Uganda in particular and other GM crops in general; (iii) the influence of preference heterogeneity on choice of banana bunch attributes among individual households, and between urban and rural households; (iv) the consumers' willingness to pay for the values accruing from GM bananas given a farm level benefit; and (v) the overall assessment of the effects of introducing GM bananas and its implications on banana producers and consumers in Uganda. These issues hold numerous implications for scientists, policy makers (regulators), the public, and other stakeholders. The aim of this chapter is to mention and discuss a range of these implications.

The contribution is structured as follows. The next section presents the overall approach and explains its application. Section 7.3 reports the main results. The policy implications of the empirical findings for decision-making on biotechnology and biosafety regulations in Uganda for GM banana in particular, and other GM crops in general, are discussed in the final section including suggestions for future research.

## 7.2 Approach and implementation

The framework of the research comprises two approaches, real options and choice experiment (CE). The latter relates the economic benefits to potential consumers' concerns. Primary and secondary data sources were used for this study. Primary data was obtained from a survey of 421 households drawn with a random sample stratified into rural and urban households. The survey questionnaire was designed to collect information on the respondents' observed characteristics as explained in chapter three of the thesis, and administered in July and August 2007. First, each respondent was asked questions about his/her knowledge, attitudes and perceptions (KAP) regarding GM crops and food. In part two, social, demographic, and economic information on the households were collected, including the characteristics of the banana purchase decision-maker(s) and other members of the household. The final part consisted of the CE. Secondary data on banana production and consumption are taken from the database of a NARO/IFPRI project conducted between 2003 and 2004 in Uganda. The data set is complemented by data for banana production of 1980 through 2004 obtained from the Uganda Bureau of Statistics (UBOS) and the Food and Agriculture Organization.

Different econometric models were applied to the data sets to test hypotheses related to five research questions. A real option model was used to estimate the maximum incremental social tolerable irreversible costs (MISTICs) for GM banana, providing a maximum threshold value for consumer perceived irreversible costs of introducing GM banana. An explanatory factor analysis was applied to investigate the underlying latent structure of the KAP data. Random parameter logit models and latent class models were then applied to investigate consumers' preference heterogeneity for banana attributes in the choice data. Finally, I compared the MISTICs with the willingness to pay for GM bananas to derive policy implications.

## 7.3 Overview of findings

To achieve the overall aim for this study, five research questions were addressed. This section presents the highlights for each research question.

Research question one:
*What are the expected social incremental benefits and costs under effects of irreversibility, flexibility and uncertainty of introducing genetically modified bananas in Uganda?*

A real option approach was followed in order to calculate the maximum incremental social tolerable irreversible costs (MISTICs) and the social incremental reversible benefits (SIRBs) of introducing a GM banana in Uganda. The MISTICs associated with the adoption of a GM banana in Uganda were calculated and presented for different risk-free and risk-adjusted rates of return. The results show the MISTICs to be between approximately US$176 million and US$359 million per year, or between US$282 and US$451 per hectare per year. In the scenario with a risk-adjusted rate of return of 12% and a risk-free rate of interest of 4%, which I considered to be a reasonable scenario based on the results of Mithöfer (2005), the annual MISTICs per household are about US$38. This result can be interpreted as follows: the immediate release of the GM banana should be postponed or abandoned only if the average household is willing to give up more than US$38 per year for not having such a banana introduced.

In the case where approval of the GM banana is delayed due to missing regulatory procedures and protocols, Uganda will forego potential benefits (SIRBs) in the approximate range of US$179 million to US$365 million per year. This foregone benefit can be an indicator of how much Uganda can pay to compensate for potential damages. Additionally, the SIRBs provide a clue about the maximum costs farmers would endure in order to comply with biosafety regulations, including the cost of implementing coexistence policies and after deducting planting costs of US$101 per hectare. In a reasonable scenario, for instance, the average SIRBs total about US$303 per hectare. Adopters of the GM banana would not be willing to pay more than US$200 per hectare per year in transaction costs—that is, costs to comply with additional regulations. Those additional regulations may include regulations for planting GM banana at farm level addressing biosafety or coexistence issues to address consumer concerns. As the US$200 per hectare are social benefits they also provide a justification for spending additional money to address consumer concerns through information campaigns and other means. This provides the following interpretation of the MISTICs. If the average WTP per hectare of a banana-growing household is below the MISTICs but biosafety regulators are inclined to implement biosafety regulations to address concerns of consumers with a high WTP for not having the GM banana, those additional costs should not exceed US$200 on average per year per hectare of GM banana. Assuming a maximum of 541,530 hectares that may be planted with GM banana in Uganda, this implies that the maximum total costs to bring the GM banana to Ugandan producers should not exceed US$108 million. Otherwise, the GM banana is not a viable alternative.

Based on the MISTICs results, it is evident that Uganda loses from not introducing a fungal resistant GM banana. But only if the average household is willing to give up more than US$ 38 annually for not having GM bananas introduced should an immediate release considered to be postponed. This analysis demonstrates a relationship between agricultural policy, R&D, technology delivery and impact, which shows an inverse relationship between stringency (precautionary approaches) and technology delivery. That is, the more stringent the approval process, the more potential benefits are foregone annually, which impacts both the scientists and the technology end users negatively.

Chapter 2 provides two new contributions to the economics of biotechnology literature in developing countries. First, I present a general approach for assessing ex-ante the economic benefits of introducing a GM banana in Uganda under uncertainty and irreversibility. The application of the MISTICs approach pays closer attention to the application of the precautionary principle within the assessment of GM crops (Just, Alston, and Zilberman 2006). It is important to note here that this is the first application of the MISTICs approach in a developing-country setting, and in the biosafety debate. Second, although some ex ante studies (cf Kalyebara, Wood, and Abodi 2007; Qaim 1999) have assessed the economic benefits of biotechnology in the region, uncertainties about the benefits and costs as well as irreversible environmental concerns were not modeled explicitly. Chapter 2 does so.

Research question two:
*What are the consumers' knowledge, attitudes, and perceptions toward introducing genetically modified bananas in Uganda, how do they differ between rural and urban households, and do consumers know, and have trust in, the institutions responsible for regulating GM crops in Uganda?*

As little is known about consumer knowledge, attitudes and perceptions (KAP) toward GM banana in Uganda, an explanatory factor analysis was applied to investigate the underlying latent structure of the KAP data. The analysis of KAPs results in three categories including benefit, food-environment risk, and health risk KAPs. The KAP toward GM crops among rural and urban consumers vary owing to a number of socioeconomic characteristics, suggesting a rural-urban bias. Given quality benefits, consumers are more willing to accept GM banana but at the same time they are concerned about the unknown negative effects of the technology. Results show that rural consumers value the quality benefits, while urban consumers are more concerned about the safety of the technology. Education and income have negative effects on GM banana acceptability. Results further indicated that there is a relatively high level of awareness and trust in local leaders and extension workers. Respondents were less aware of the Uganda National Council of Science and Technology (UNCST) and the Consumer Education Trust (CONSENT), the two main agencies responsible for informing consumers about GM food.

In conclusion, I would argue that delaying the approval of a fungal resistant GM banana in Uganda is more in line with the preferences of urban than rural consumers and in particular the better educated and wealthier ones. But how can the negative perceptions among the urban and wealthier ones become positive or neutral at best? There is a need to ensure transparency of and participation in the approval process, but need to be balanced with the feasibility of doing so. However, if the system is not participatory and does not respect dissenting opinions, then legitimacy is taken from the system. If this is the case, then people tend not to respect the regulatory system. The main lesson is for the National Agricultural Research Organization and the Government of Uganda to develop in advance communication strategies to ensure proper discussion and certainly address potential concerns.

Exploring consumers' knowledge, attitudes, and perceptions (KAPs) and institutional awareness in relation to the introduction of a GM banana contributes to one of the caveats mentioned by Smale, et al. (2009). The authors proposed, "given the rapidity of change in this field of science and the quantity of information to which consumers are exposed, estimates of perceptions and WTP may need to be continually updated for the information to be of use in marketing ". This chapter provides a contribution.

Research question three:

*How does preference heterogeneity influences choice of banana bunch attributes across individual households, and what are the differences between the consumer preferences for urban and rural households towards banana bunch attributes?*

The heterogeneity in consumers' preferences for different banana attributes in Uganda was investigated using choice experiment data. The analysis of the choice data took into consideration preference heterogeneity resulting from locational and household level characteristics. This helped to test whether consumers in rural and urban locations value banana attributes differently. A random parameter logit model was applied to investigate the heterogeneity preference for the banana bunch attributes. Interactions of respondent-specific household characteristics with choice-specific attributes in the utility function were included in the model to account for the source of unobserved heterogeneity. This provided insights about differences in consumer valuation of the GM technology in addition to understanding the aggregate economic value associated with such technology, similar to the policy-change effect as analyzed by Boxall and Adamowicz (2002). Findings reveal that there is substantial conditional and unconditional heterogeneity, as accounted for by the random parameter logit model with interactions, carried out for each location (urban and rural) separately. The impacts of social and economic characteristics of the consumers on their valuation of the banana bunch attributes were significant, indicating the importance of considering such characteristics in explaining the sources of conditional heterogeneity. Even though bunch size is valued highly by both rural and urban households, urban and rural preferences differ towards the introduction of a GM banana. The low-income rural households with larger household sizes value the GM technology that generates benefits to producers more highly than the urban ones. Conversely, respondents with higher education were found to be more critical toward the GM technology, which would negatively influence their willingness to accept the GM banana. In this line, statistical tests confirm that there are significant differences in preferences for banana bunch attributes between urban and rural households in Uganda.

The application of the econometric models in this section supports two conclusions. First, a connection needs to be established between banana attributes and crop improvement efforts. In that sense, there is a need to link plant breeders, consumers, producers and decision makers. For instance, the findings show that bunch size matters a lot for both rural and urban respondents. Breeding efforts, therefore, should concentrate on improving bunch size but without forgetting other quality attributes. Second, increasing the importance of consumers, producers, and producers that happen to be consumers, participation in the decision-making process for approval and in marketing chains can help to reduce negative perceptions. This is important, not only because of the benefits, but also because of negative responses such as anti-GM banana campaigns this may trigger otherwise.

Research question four:

*How much are consumers' willing to pay for the values accruing from GM bananas given a social benefit, and how does it compare across different consumer segments?*

Unlike in the previous section where models with interactions and split samples were used to explain heterogeneity of preferences at individual level, to answer this question I employed a latent class model (LCM), which is a more recent model to investigate preference heterogeneity. The LCM has been successful at identifying the sources of heterogeneity at the segment level, unlike the covariance heterogeneity (CovHet) and random parameter logit (RPL) models which capture heterogeneity at the individual level. Investigation of heterogeneity at the segment level would be most policy relevant when assessing the welfare impact of introduction of a technology, such as a GM food product, on different segments of the population (see e.g. Birol, Villalba, and Smale 2009; Kontoleon and Yabe 2006; Hu et al. 2004). This 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 from one segment to another. The number of segments is determined endogenously by the data. The fitting 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, perceptions and attitudes. Furthermore, respondent characteristics affect choices indirectly through their impact on segment membership.

This analysis involved, first, testing further whether or not preferences of urban households differ from preferences expressed by rural households. Second, this study included as one of the attributes welfare benefits for producers. Producer benefits often have not been considered in studies on consumer preferences towards GM food and I expect these to have a positive effect on consumers' preferences, similar to the results reported by Loureiro and Bugbee (2005) and Gaskell et al. (2006).

The findings show that there is significant heterogeneity in consumer preferences in the sample. The analysis identified two distinct segments of banana consumers, the *potential GM banana consumers (*representing 58 percent of the sample and residing more in rural areas), and the *potential GM banana opponents* (representing 42 percent of the sample, with the majority found in urban areas). GM banana is valued the most by poorer households who are located in the rural areas of the Eastern Region, where banana pests and diseases are prevalent. These consumers are also 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 have relatively lower monthly incomes. They would be willing to pay larger premiums for GM bananas and to ensure producers of bananas derive higher benefits. The empirical findings support Edmeades and Smale (2006) who argue that clients of GM banana planting materials are likely to be the poorer, subsistence-oriented households in regions greatly affected by biotic pressures. These results are also consistent with results for questions 2 and 3. The utility of the *potential GM banana opponents'* segment mainly representing urban consumers decreases with the introduction of GM banana, which generates benefits to producers. These consumers would therefore be willing to accept a discount for both GM bananas and benefits to producers. Most of these consumers are older and better off; they reside mainly in urban areas of the Southwestern Region and Central Region, and mostly associate GM banana with risks (i.e., food, environment and health risks). The total WTP among those who gain from the introduction of the GM technology (the *potential GM banana consumers*) and the total willingness to accept for those who lose due to this technology (the *potential GM banana opponents*) are significant and large. Further research is required to investigate these welfare impacts and to determine whether or not the *potential GM banana consumers* (the majority of whom are rural consumers) can potentially compensate the *potential GM banana opponents* (mostly urban consumers) if a GM banana is introduced in Uganda.

The latent class econometric analysis supports several conclusions related to the introduction of GM banana in Uganda. First, findings confirm that GM banana could be a potentially pro-poor biotechnology, and its introduction would benefit the most rural households who grow and buy banana. Second, I find support for Paarlberg's (2008) argument that '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. Empirical findings suggest that better educated people are on average more strongly opposed towards GM banana and this not only in urban areas but also in rural. Third, 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. But findings indicate that stressing the potential benefits the technology may provide to farmers is more likely to increase the opposition towards GM banana among the urban consumers. This finding does not support my expected a priori, and differs from other findings in literature, e.g. Gaskell et al. (2006 and Loureiro and

Bugbee (2005). The authors found consumers to have positive willingness to pay for GM crops that increase profits for farmers. Finally, the main lesson learned is that if preference heterogeneity of consumers is not considered, then the results are likely to be biased. Therefore, for studies that seek to explore consumer preferences, heterogeneity is the departing hypothesis. This has implications for study design, scope, and selecting best practices for evaluation purposes.

The contribution of chapters 4 and 5 to the growing literature of consumers' willingness to pay is three-fold. First, linking both the consumers and adopters of the technology in one analysis—as proposed by Smale et al. (2009)—is new, especially in a developing country setting. Second, the inclusion of benefits for producers as an attribute in consumer preferences towards GM food often have not been considered in studies on consumer WTP. Third, contribute to debate of how African elites view GM food, as argued in Paarlberg's (2008) book.

Research question five:

*What are the impacts of introducing GM bananas on food security in Uganda, and what implications does this have for biosafety regulations in general?*

The empirical findings estimated to answer questions 1, 2 and 4 are integrated in an economic welfare analysis to provide an overall assessment of the effects of introducing genetically modified bananas on banana producers and consumers. The maximum incremental social tolerable irreversible costs (MISTICs) associated with the immediate introduction of a GM banana were compared with the estimated total willingness to pay (WTP) values for the GM banana for different scenarios. I applied the concept of compensating surplus to consumers' preferences for a GM banana, and made simulations based on different combinations of impacts associated with GM banana introduction strategies to estimate the consumers' welfare measures. Welfare measures were estimated for the best-fit latent class model.

The findings showed that there are respondents who gain and who lose from the introduction of a GM banana in the data, which is consistent with results in the previous section. The total welfare for those who gain (*potential GM banana consumers*) is greater than the total welfare for those who lose (*potential GM banana opponents*). The findings suggest that the *potential GM banana consumers* can potentially compensate the *potential GM banana opponents* if a GM banana is introduced in Uganda, which is in accordance to the Hicksian compensation criterion (Just, Hueth, and Schmitz 2004). The *potential GM banana consumers*, who are mostly located in rural areas, show a much higher willingness to pay for all the proposed GM banana alternatives, particularly a GM banana which is characterized by large bunches and large benefits to producers. With this finding, it is evident that benefits to producers played a significant role in the valuation of the banana bunch attributes. These results imply that if a GM technology can improve crop productivity, and hence increase incomes of the rural subsistence households, that technology would be easily accepted among the rural population segment as reported here. Nonetheless, when the *potential GM banana opponents'* households are considered further, their total WTP for the proposed banana improvement scenarios were negative and the absolute value above their estimated average MISTICs per bunch. With this finding I argue that, on the one hand, the *potential GM banana opponents* are likely to pay more than the threshold value of not having a GM banana introduced in Uganda. On the other hand, however, the calculated MISTICs per bunch for the *potential GM banana opponents'* households were generally low, which range approximately between US$ 0.15 and US$ 0.36. This implies that if the biosafety regulators are to address the concerns of the *potential GM banana opponents*, those additional costs may not exceed the potential benefit ranging between US$ 179 to 365 million per year. There will be still enough to compensate for the negative effects if a fungal resistant GM banana is introduced. The aggregate welfare showed improvement in welfare over status quo for all scenarios, which is highest when a GM banana with large bunches and medium benefits is proposed. This implies that if a fungal resistant GM banana with such attributes is introduced now, its introduction may result in strong opposition from the *potential GM banana opponents*' segment of the population, which is composed of mainly urban consumers.

Based on the empirical findings in this section, the following conclusions can be derived. First, the GM banana technology is likely to improve the overall welfare in Uganda, but we need to think carefully about those who may lose from the introduction of this technology. Thinking about this beforehand can reduce the negative impact the *potential GM banana opponents*' segment. Second, a comprehensive cost benefit analysis, using different approaches, would be of great importance for assessing the potential benefits and costs of introducing new technologies—such as GM bananas. The net social costs or benefits of most GM crops are likely to be crop-specific, especially in terms of food and environmental safety issues. Introduction strategies would need to consider the distribution of potential costs and benefits for these new GM crops before a decision to introduce is made.

The major contribution of chapter 6 to literature is the integration of the MISTICs with the consumers' willingness to pay (WTP) for a GM banana. The chapter explicitly analyses the impact of introducing the GM banana on banana producers and consumers based on the results of the two approaches.

## 7.4 Policy implications

The results indicate that with each year of delay in the introduction of a GM banana, Uganda loses about US$179 million to US$365 million. The MISTICs are about US$176 million or more. Only if the real average annual irreversible costs of planting a GM banana would be as high, or higher than, the irreversible benefits, should the release be delayed. I have found no evidence yet that this will be the case. Given the potential and significant economic benefits from the introduction of a GM banana, one might conclude that NARO has to work harder to push the GM banana through the biosafety protocols as promptly and efficiently as possible.

Findings have revealed that government policies delaying the introduction of genetically modified bananas are more in line with the views of wealthier and better educated citizens, the elites, than with the views of the majority of the population. While this is a disturbing observation as mainly rural households economically gain from the introduction of a GM banana crop, a careful approach towards introducing GM banana is needed to avoid strong urban consumer resistance. In that case, knowing who will be affected by the new innovations, and by how much is fundamental in foretelling possible problems of introduction.

The findings have further shown that the introduction of GM bananas could be beneficial for the Ugandan society as a whole, and would merit policy support, albeit with consideration of compensation mechanisms aimed at transferring some of the benefits from gainers to losers. Some of the ways of compensation can be providing more and reliable information about the safety of the technology, which could be channeled through (in addition to the current institutions) local authorities and extension workers. Findings have shown that there is high level of awareness and trust in local leaders and extension workers and low awareness of Uganda National Council of Science and Technology (UNCST) and Consumer Education Trust (CONSENT), the two main agencies responsible for informing consumers about GM food. This presents an opportunity for informing consumers about GM food through local leaders and extension workers. I would recommend instead of UNCST and CONSENT informing consumers directly they may also use part of their resources for training local leaders and to enlist their help in spreading information. This strategy can help offsetting the negative knowledge, attitudes and perceptions toward GM technology, especially among urban consumers.

The approach used here highlights how one can evaluate the socioeconomic aspects of GM crops in general, linking both the consumers and adopters of the technology. I have also indicated how one can consider long-term but highly uncertain irreversible effects and how one might assess consumer attitudes toward GM crops. Empirical research, along the lines of the methodology followed in this study, can be adapted to investigate consumer reactions towards new GM crops that have passed the biosafety assessment prior to commercialization and can help to overcome some of the problems an introduction in Uganda and other developing countries in general may face. In particular, NARO may institutionalize the approach suggested in this study and build a system that allows for conducting similar analyses of other GM crops—such as Bt cotton currently undergoing environmental and food safety assessments. Institutionalizing such an approach may also move ahead the establishment of a biosafety policy.

Finally, there is a need to broaden the scope of biosafety processes now primarily focused on risk to include food security considerations and agricultural development. This calls for more funding for R&D. Findings have revealed that if a technology has tangible benefits, which could improve the incomes of subsistence farmers, that technology could find its way easily to the end users. However, the research agencies that could develop such technologies are financially constrained. For instance, NARO, the main agricultural research agency which accounts for over three quarters of the agricultural research budget in Uganda (Agricultural Science and Technology Indicators, ASTI 2002), has received less budget for the Fiscal Year (FY) 2009/10. The budget for agricultural R&D funded by the Government of

Uganda has decreased from 12.6 percent of the total Agriculture budget in FY 2008/2009 to 11.4 percent in FY 2009/2010. Similarly, the donor funding for agricultural R&D through NARO, has also decreased from 30.0 percent of the total agriculture budget in FY 2008/2009 to 19.2 percent in FY2009/10 (GOU 2009). Yet modern biotechnology was embraced as one of the priority areas targeted by the government to increase incomes and improve the quality of life of the poor subsistence farmers through increased productivity and increased share of marketed production (Oxford Policy Management 2005). The study shows additional financial resources are needed for informing potential opponents about the benefits of the technology as otherwise resources spent might be wasted.

## 7.5 Limitations and recommendations for future research

The choice experiment approach used to collect the data for the model simulations involved mainly the use of surveys of relevant decision makers. It involved collection of data from both producers as consumers (who are the likely potential adopters) and the sole consumers of banana. The choice modeling technique follows a Lancaster utility approach for analyzing relative importance of product attributes within a relevant product choice set. However, stated preference approaches are subjected to various criticisms. The most important limitation of the choice experiment noted by List and Gallet (2001), akin to other stated preference methods, is that little may be generated from a hypothetical market about the real market behaviors as result of disparities between hypothetical and actual statements. This issue, however, has been addressed by numerous authors. Recently, List, Sinha, and Taylor (2006) compared choice experiments with hypothetical and real situations. In their experiment, the authors informed respondents about the hypothetical bias problem through “cheap talks” and reminded the respondents to take care when making their choices. The authors found no statistically significant differences between hypothetical and real willingness to pay or when estimating the marginal values of attributes. In this study, respondents were informed about the ongoing biotechnological innovations in Uganda using brochures prior to the interviews. They were also reminded that there were no right or wrong answers and that they should consider their choices carefully. In addition, Lancaster (1966) recommended that in order to determine the product attribute, it is very important to contact the potential consumers directly.

In this study, informal interviews with consumers such as focus group discussions were used to develop and design the questionnaire, which was later pre-tested on both rural and urban consumers prior to primary data collection. With a view to the caveats discussed the findings support Edmeades and Smale (2006)—who used a revealed preference technique to predict the demand of genetically modified banana planting materials. However, an empirical investigation comparing hypothetical and real market situations could be warranted.

In the empirical analysis of the social incremental reversible benefits (SIRBs), the data for non-private net benefits were not available in the public domain. Hence, the SIRBs were estimated based on private net benefits. Furthermore, when estimating the MISTICs, I did not include the transaction costs that might be involved between the technology developers and the end users, including R&D costs, compliance with biosafety regulatory costs, and technology fees[1]. Such costs can be substantial and are one of the major obstacles to technology dissemination in developing countries such as Uganda (Brenner 2004). The problem is not limited to GM technology but to embodied technologies in general. Adding such costs will reduce the SIRBs. Again, they should on average not be more than the SIRBs per hectare, and should be even less if biosafety regulatory costs at the farm level are added. Another limitation is that the MISTICs calculated in this study were generally for Uganda as a country; however, they are likely to vary by region and even by cultivar. Edmeades (2003) notes the diversity of banana cultivars is high at the country, village, and household levels. On average, 23 different banana cultivars are grown at the village level across Uganda, with approximately five different cultivars of cooking bananas grown per household. Households located in the high elevation areas such as the Southwestern Region were found to grow more cultivars compared to those in the low elevation areas (e.g. the Central Region and most parts of the Eastern Region). This suggests that MISTICs may be larger for regions (or households) where banana production is high compared to the rest with low banana production. Hence, these issues necessitate future empirical research.

Finally, the findings reported in this thesis have shed light onto the differences between the urban and rural consumers' preferences of the banana bunch attributes. However, future research is required to understand in more detail why urban consumers as well as rural and urban elites derive disutility from the introduction of a GM banana and the associated

[1] As technology fees charged by innovators are used to recover R&D costs and biosafety costs, it is imperative to include such costs as net costs to society avoid double-counting.

benefits for producers. In addition, additional empirical research is needed to find more mechanisms through which those who gain may compensate those who lose in case GM bananas or other GM crops are introduced.

**A final remark…**

A comprehensive analysis of the socioeconomic impacts of introducing GM crops in Uganda in particular and Africa in general requires the consideration of various stakeholders. Introducing such crops can be expected to improve the livelihood of rural subsistence farmers through increased crop productivity. However, their introduction depends on consumers' knowledge, attitudes and perceptions, especially the perceived health and environmental effects. The research findings reported here show that introducing a GM banana would be beneficial to the Ugandan society as a whole, but its introduction may result in strong opposition from the loser segment of the population. Based on this case study biosafety regulators would need to consider these socioeconomic effects before a decision to introduce is made. However, the decision to consider socioeconomic impacts for other GM crops elsewhere depends on the crop and the country. The research methodology in this thesis can provide the basis for empirical studies for other crops.

# Appendices

## Appendix A.1. Banana producers and consumers survey in Uganda

The survey included the following, which are presented in a chronological order:

1. The introduction letter
2. CONSENT materials on biotechnology and biosafety awareness
3. Additional information on genetically modified organisms, in particular GM banana
4. Visual aids showing the diseases affecting banana
5. A hypothetical press release
6. The questionnaire

**1. Introduction letter**

Good day! We work with the National Agricultural Research Organization (NARO). We are conducting a survey to understand your attitudes and perceptions regarding genetically modified crops (products). This study is being conducted in different parts of the country namely; central, eastern and southwestern Uganda.

Your household was randomly selected to be part of this study. You will be asked some questions about your opinion on several issues related to food safety, environmental safety and hypothetical shopping. It will take between 45 minutes to 1 hour to complete this questionnaire. We therefore request for your patience during this activity. I am assuring you that all the information given will be confidential and only used for this study.

In addition, there is no right or wrong answer; we're only interested in your opinions. Please take a note that genetically modified crops are not yet in Uganda.

If anything is not clear, please do not hesitate to ask. We will try to answer your questions.

## 2. CONSENT materials on biotechnology and biosafety awareness

## Awareness material in English

### 1. What is Biotechnology?

Biotechnology is any technique that makes use of organisms (or parts thereof) to make or modify products, to improve plants or animals, or to develop microorganisms for specific purposes. It dates as far back as 7000 BC with brewing beer and 4000 BC associated with Egyptian leaven bread with yeast.
It has two components: traditional biotechnology and modern biotechnology as in tissue culture, hybridization and genetic modification.

### 2. What are GM products and how are they made?

GM products are products that have a novel combination of genetic material obtained through the use of modern biotechnology - genetic modification. Genetic modification involves the transfer of genes into other organisms whether related or not to achieve the desired aim.

**Agricultural**:
insect tolerant Bt maize and Bt cotton, Herbicide tolerant soybean, Fungal tolerant
Bananas etc.

**Foods**:
flour from GM corn (maize), soya protein blend from GM soya, GM cottonseed oil, GM fish, processing enzymes, nutritional additives etc.

**Medical**: vaccines, drugs
Industrial: yeast, fuels, enzymes and plastics

### 3. Why make GM products?

GM products are developed to enhance production processes in agriculture, health, industry and product quality as in food, drugs, vaccines etc and to address global challenges such as food shortages, malnutrition, health epidemics, population growth, biodiversity conservation among others, inspite of the current uncertainties associated with it.

### 4. Potential benefits of GM products

GM products/technologies have a number of benefits. These include:

- Cost effective production in health/pharmaceutical processes and agriculture
- Enhanced industrial processes
- Higher crop yields
- Reduced farm costs
- Increased farm profit
- Improvement in health and the environment

### 5. Public Concerns about GM products/technologies

Although the technologies and products have potential benefits, there are certain public concerns that need to be addressed. These include:

- Human and environmental safety
- Infringement on consumer choice
- Infringement on farmer / community rights
- Allergens and other antinutrition factors in foods
- Biodiversity contamination and degradation
- Ethical concerns of altering nature
- Pesticide and toxin resistant pests
- Herbicide resistant weeds

### 6. Can the concerns be addressed?

It is the obligation of the technology innovators (i.e. scientists), producers, and the government to assure the public of the safety of the novel products like foods that they offer as well as their effect on the society and environment. This could be done through:

- Establishment of Policy and Legal Frame work for regulating use of biotechnology
- Enhancement of regulatory institutions
- Enforcement of legal/regulatory instruments with effective steps to mitigate these risks
- Use of risk management methods to reduce risk to an acceptable level as there is no zero risk

### 7. Are GM products appropriate for Uganda?

*GM products can be appropriate if:*

i. scientific capacity is enhanced to assess the biosafety and appropriateness of GM products/technologies,

ii. socio-economic experts evaluate their costs and benefit in short and long term,

iii. regulatory capacity exists to implement safe deployment, and

iv. the legal and institutional framework to enforce compliance with biosafety requirement through appropriate means (fines and penalties).

The above could be applied on a case by case basis under a precautionary approach through informed decision making by stakeholders.

## 8. Stakeholder Action

*Stakeholders should:*

- Engage in the biotechnology/GM debate given the importance of food, health and sustainable development to Uganda.
- Call for open and honest debate involving all stakeholders.
- Access accurate and balanced information on biotechnology
- Participate to build your understanding, community capacity and add your informed opinion to discussions about acquisition, deployment, and monitoring of GM technologies/products.

## 9. For further information contact:

- Consumer Education Trust (CONSENT) - Desai House Parliament Avenue,
- Uganda National Council for Science and Technology (UNCST) - Uganda House,
- National Agricultural Research Organization (NARO), and
- Some of the resourceful Websites:

www.biosafetynews.com,
www.fao.org,
www.who.int,
www.isaaa.org,
www.bio.org,
www.agbiodafety.unl.edu,
www.foei.org,
www.absfafrica.org,
www.whybiotech.com,
www.europa.eu.int,
www.indsp.org

# Biotechnology Awareness CAMPAIGN

CONSENT
BIOTECHNOLOGY
AWARENESS CAMPAIGN

**Consumer Education Trust (CONSENT)**
enhancing public-private partnership and dialogue
Tel: 256 - 31 - 260 431 or 256 - 77- 502 441
Email: consentug@yahoo.com

## Awareness Material in Luganda (local Language)

# Kaweefube W'okumanyisa Tekinologiya W'obutonde

CONSENT
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AWARENESS CAMPAIGN

CAMPAIGN

1. **Tekinologiya w'Obutonde kye kki?**

Tekinologiya w'Obutonde ke kakodyo konna akakozesa ebintu ebiramu (oba ebitundu byabyo) mu kukola oba mu kukyusa ekintu, okulongoosa ebimera oba ebisolo, oba okukola obuntu obussirikitu olw'emirimu egy'enjjawulo. Enkola eyo yava dda eyo mu mwaka 7000BC mu kusogola omwenge, ne mu mwaka 4000 BC Abamisiri bwe baafumbanga emigaati n'ekizimbulukusa, yeast. Erimu ebitundu bibiri, tekinologiya w'obutonde ow'obuwangwa ne tekinologiya w'obutonde ali ku mulembe ng'ow'okutandika okukula kw'ebimera mu laboratory, okukola olulyo olulungi, n'okukyuusa obutonde bw'ekintu.

2. **Biki ebikolebwa oluvannyuma lw'okukyusa mu butonde bwabyo era Bikolebwa bitya?**

Ebintu ebikolebwa oluvannyuma lw'okukyusa mu butonde bwabyo birimu ekintabuli ky'ebintu ebipya ebyakolebwa mu kweyambisa tekinologiya w'Obutonde ow'omulembe - ow'okukyusa mu butonde bw'ekintu. Okukyusa mu butonde kwe kuddira obutafaali bw'obutonde bw'ekintu n'obugatta n'obutafaali bw'obutonde obulala, obufaanana oba tebufaanana, olw'okwagala okutuuka ku ky'oluubirira okukola.

Ebimu ku bintu ebikolebwa oluvannyuma lw'okukyusa mu butonde bwabyo . ebya tekinologiya w'obutonde.

Eby'obulimi: Kasooli wa Bt ne Pamba wa Bt, atalibwa biwuka, soya ataliibwa biwuka, amatooke agatabaako nkonge, n'ebirala.
Emmere: Obuwunga obuva mu kasooli akyusiddwamu, Ensigo za Pamba akyusiddwamu, Ebyennyanja ebyakyusibwamu mu butonde bwabyo, ebikozesebwa mu kulongoosa n'okuwangaaza ebintu ebiva mu makolero, n'ebyongera mu mmere ekiriisa.
Eby'obusawo: eddagala erigema n'erijanjjaba.
Amakolero: Yeast, amafuta, enzymes ne plastic.
Eby'obutonde: enkola n'obukodyo ebikozesebwa mukulongosa oba o'kugogola obutonde ssinga buba bwononeddwa mungeri emu oba endala.

3. **Lwaki tukola ebintu ebirongooseddwa mu butonde bwabyo?**

Ebintu ebirongooseddwa mu butonde bwabyo bikolebwa olw'okutumbula eby'obulimi, eby'obulamu, amakolero, awamu n'okutumbula omutindo gw'emmere, eddagala, n'ebirala, olw'okusobola okwang'anga obuzibu mu mawanga gonna ng'obw'ebbula ly'emmere, okulya emmere etaliimu kiliisa, okugwawo kw'obulwadde obw'akabi, okweyongera kw'obungi bw'abantu, okukuuma ebintu ebiramu eby'enjjawulo ebisinangibwa mu kitundu, n'ebirala, newankubadde nga waliwo okubuusabuusa enkola eno mu kiseera kino.

4. **Emiganyulo egiri mu bintu ebikolebwa oluvannyuma lw'okukyusa obutonde bwabyo.**

Ebintu ebikolebwa oluvannyuuma lw'okukyusa mu butonde bwabyo/tekinologiya birina emiganyulo nfaafa, omuli bino:

- Kitwala ssente ntono okukola ebikozesebwa mu by'obulamu ne mu kutabula eddagala awamu ne mu by'obulimi.
- Byanguya emirimugy'omu makolero.
- Byongera okubala kw'ebirime.

- Bikendeeza ssente ezikozesebwa ku nnimiro.
- Byongera ku magoba agava mu nnimiro.
- Bitumbula omutindo gw'eby'obulamu n'obutonde bw'ensi.

**5. Obweralikirivu bw'abantu ku bintu ebikoleddwa oluvannyuma lw'okukyusa mu butonde bwabyo/tekinologiya.**

Newankubadde tekilogiya n'ebintu ebikole birina emiganyulo, waliwo obweralikirivu bw'abantu abamu obusaanidde okukolebwako, nga:

- Okukuuma abantu n'obutonde bw'ensi.
- Okuyingirira eddembe ly'akozesa okweronderawo.
- Okuyingirira eddembe ly'abalimi awamu n'abantu abalala.
- Ebintu ebitali birungi n'ebirala ebimala ekiriisa mu mmere.
- Okwonoona n'okumalawo ebitonde ebitali bimu.
- Obweralikirivu bw'okukyusa obutonde.
- Ebiwuka eby'akabi ebigumira eddagala eryandi bisse.
- Omuddo ogugumira eddagala ly'omuddo.

**6. Obweraliikirivu buno busobola okukolebwako?**

Buvunaanyizibwa bw'abakozesa tekinologiya ono (bannasaayansi), abakola ebintu, awamu ne gavumenti okukakasa abantu ng'ebintu eby'enkola empya bwe bitalina mutawaana, ng'emmere gye bakola awamu n'ebintu ebirala ebikola ku bantu awamu ne ku butonde bw'ensi. Kino kiyinza okukolebwa okuyita mu makubo gano:

- Ekuteekawo enkola n'omusingi gw'amateeka ag'okupima enkozesa ya tekinologiya w'obutonde.
- Okwongera amaanyi mu bitongole bino.
- Okukwasisa amateeka/amateeka agapima nga galimu amadaala agakola ku bizibu bino.
- Okweyambisa enkola eyetangira akabi olw'okusobola okukendeeza ennyo obubenje kubanga obubenje tebwewalika.

**7. Ebintu ebikyusiddwa mu butonde bwabyo bisaanira mu Uganda?**

i. Saayansi asobola okulaba obanga obutonde buli mu katyabaga oba nedda era n'okuzuula oba nga ebintu ebikolebwa n'okukyusa mu butonde bwabyo ne tekinologia bisaanira.
ii. Abakugu mu mbeera z'abantu ne mu by'enfuna babalirira ssente ze bitwala mu kiseera ekimpi n'ekiwanvu,
iii. Obusobozi we buli obw'okupima engeri gye bikozesebwamu obulungi, awamu
iv. N'omusingi mu mateeka ogw'okuwasisa ebiragiro ebikwata ku kwerinda kw'obutonde ng'aabigondera atanzibwa oba aweebwa ekibonerezo.

Ebiri waggulu biyinza okukozesebwa mu mbera nga bw'eba eyimiridde n'okukwata ekkubo ly'okwerinda nga liyita mu kusalawo okulung'amu ne bekikwatako.

**8. Be kikwatako kye balina okukola**

- Beetabe mu kuwayisiganya ebirowoozo ku bintu ebikolebwa oluvannyuma lw'okukyusa mu butonde bwabyo okusinziira ku bukulu bw'emmere, eby'obulamu n'okutebenkera kw'okukulaakulana mu Uganda.
- Okuteekawo okuwanyisiganya ebirowoozo okwesimbu nga kulimu be kikwatako bonna.
- Okufuna ebyetaagibwa okumanyibwa byonna ebituufu ebitaliimu kyekubiira ku bintu ebikolebwa oluvannyuma lw'okukyusa mu butonde bwabyo.
- Mwenyigire mu kuzimba okutegeera kwammwe, obusobozi bw'abantu, era ogatte ebirowoozo byo eby'okumanya mu kukubaganya ebirowoozo ku kufuna, okukozesa, n'okulondoola ebintu ebikolebwa mu kukyusa mu butonde bwabyo ne tekinologiya.

**9. Ng'oyagala okumanya ebisingawo tuukirira:**

- Consumer Education Trust (CONSENT) - Desai House, Parliament Avenue,
- Uganda National Council for Science and Technology (UNSCT) - Uganda House ne
- National Agricultural Research Organization (NARO)
- Websites: www.biosafetynews.com; www.fao.org; www.who.int; www.isaaa.org; www.bio.org; www.agbiosafety.unl.edu; www.foei.org; www.absafrica.org; www.whybiotech.com; www.europa.eu.int

Obubaka bwa:

**Consumer Education Trust (CONSENT)**
Enhancing public-private partnership and dialogue
Tel: 031 260431 oba 077502441.
Email: consentug@yahoo.com

## 3. Additional information about biotechnology and Genetically Modified Organisms

Biotechnology is any technique that makes use of organisms (or parts thereof) to make or modify products, to improve plants or animals, or to develop microorganisms for specific purposes.

Gene: A gene is a biological unit that determines an organism's inherited characteristics.
Genetic engineering (modification): This is the selective, deliberate alteration of genes by man.
GMOs**:** refer to genetically modified organisms.

Genetic modification: is one of the more salient faces of biotechnology that enables specific, useful and desirable genes to be artificially inserted in a plant or animal.
These genes can be from non-related plants, animals or microbes.
Tissue Culture: is a technique that enables a whole plant to be raised from a small amount of tissue.

**The technology used to produce the banana planting material**

Tissue culture technology enables rapid multiplication of banana planting materials that are disease-free (but not resistant) through the culturing of the actively growing part (meristem) in an appropriate growing medium *in vitro* (This type of "vaccinated" plant slows but does not stop diseases from spreading'')

Genetic Modification (GM) Technology involves insertion of a gene in banana cultivar (s), extracted from another plant, which has resistance to a given biotic constrain. With this technology, unlike tissue culture only, the planting material is resistant to diseases such as banana bacterial wilt (BBW) or black Sigatoka. Tissue culture and GM technology, therefore, gives a disease free and resistant planting material (This "vaccinated" plant stops spreading of a given disease completely).

**4. Visual Aids showing common symptoms of pests and diseases affecting banana farmers in Uganda**

**Black Sigatoka**

**Banana Bacterial Wilt**

**Fusarium Wilt**

**Weevils**

## 5. A hypothetical press release (read to respondents)

*Please read (listen to) the following news extract. It will provide you with a useful background before you answer the survey questions. This article has been composed by scientists for the purpose of this survey. It does not represent any publication anywhere or statements by anyone*

**Good News to Ugandan Farmers, a New Banana Variety has been released!**

Ugandan scientists have developed genetically modified (GM) banana varieties resistant to banana diseases such as banana wilt (*Sirimu w'ebitooke*). The scientists inserted ("vaccinated") a gene from other plants such as sweet pepper in the locally produced *matooke* varieties. They have targeted the most preferred and high yielding *matooke* varieties (e.g. *Mpologoma, Mbwazirume, Musakala*). This approach is targeted to boost the available cultural measures in fighting the diseases and save livelihoods in Uganda. The GM *matooke* will be available soon for production and consumption after testing them for environmental and food safety in compliance with biosafety regulations.

Over the last two decades, banana yield has been severely reduced by a number of pests and diseases. Among the pests that cause the highest yield damage are weevils (*kayovu*) and nematodes (*obusiringanye*). The diseases that contribute to the highest yield losses are Fusarium wilt (*todura*), banana wilt (*kiwotoka*) and Black Sigatoka (*obulwade bw'endagala*) . Banana Wilt, for instance, attacks all banana varieties resulting in absolute crop loss, if not controlled.

There is no doubt that farmers and governments have tried to make the most use of available methods to combat banana diseases and pests, especially the devastating banana wilt. The most commonly recommended cultural measures for managing banana wilt involve a set of practices that include removing the male flowers, disinfecting farming tools and using healthy planting materials. According to scientist reports, over 85% of Ugandan farmers are aware of the recommended cultural measures, but less than 35% carry them out. These practices alone might slow down but not stop the spread of banana wilt, a goal that requires developing other options to be integrated into ongoing disease management efforts across Uganda.

Scientists would like to know your opinion about the new GM banana variety.

## 6. Choice experiment household questionnaire

**Identification:**

Enumerator Name________________________________

Interview start time_______________ Interview end time________________________

Date____________

Name of household head______________________________ Name of

respondent_____________________________

**To be completed by supervisor:**
Stratum code_____________; Region_____________________;

Sub-county (LC3/Town council )_________________; Parish (LC2)_______________;

Village (LC1)________________________

Household code___________; Field edit___________; Call back required__________;

Call back completed_____________; Data entered________________.

## Part 1: Household characteristics.

Please list the members of your household (HH) in order starting from household head

| PERSON NUMBER | NAMES | **Relationship to hh head**<br>1=head of HH<br>2=husband<br>3=wife<br>5=child<br>6=grand child<br>7=sister<br>8=brother<br>9=in-law<br>10=father<br>11mother<br>12=other (specify) | **Age** *(years)* | **Gender:**<br>1=male<br>2=female | **Education** *(years in school)* | Estimated income from last year (in Ugandan Shillings) | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | Banana | Other Crops Livestock | Self Employment Salaries | Wage labour | Others (e.g. Rent, Remittances gifts, etc |
| 1 | | | | | | | | | | |
| 2 | | | | | | | | | | |
| 3 | | | | | | | | | | |
| 4 | | | | | | | | | | |
| 5 | | | | | | | | | | |
| 6 | | | | | | | | | | |
| 7 | | | | | | | | | | |
| 8 | | | | | | | | | | |
| 9 | | | | | | | | | | |
| 10 | | | | | | | | | | |

**Part 2: Consumers' purchasing behavior, Consumers' knowledge, attitudes and perceptions towards GM crops and Institutional awareness.**

2A. Factors influencing purchasing behaviors of consumers

Please rate the following characteristics to show their importance to you and your household before purchasing cooking banana?

| | Strongly disagree (1) | Disagree (2) | Uncertain (3) | Agree (4) | Strongly agree (5) |
|---|---|---|---|---|---|
| 1. Price is the most important food characteristic | | | | | |
| 2. Taste is the most important food characteristic | | | | | |
| 3. Nutrition is the most important food characteristic | | | | | |
| 4. Health safety is the most important food characteristic | | | | | |
| 5. Environmental safety is the most important food characteristic | | | | | |

2B: Knowledge, Attitudes, and Perceptions toward GM banana

Please indicate by ticking your strength of agreement or disagreement for each of the following statements from 1- 5.

| | Strongly disagree (1) | Disagree (2) | Uncertain (3) | Agree (4) | Strongly agree (5) |
|---|---|---|---|---|---|
| 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. | | | | | |
| 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. | | | | | |
| 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. | | | | | |
| 4. I would buy a GM banana bunch if it was cheaper than a non-GM banana bunch. | | | | | |
| 5. If the majority of the Ugandan people are in favor of GM food, it should be legalized. | | | | | |
| 6. I would buy a GM banana bunch if it were more expensive than a non-GM banana bunch. | | | | | |
| 7. Information about food safety and nutrition on food labels can be trusted. | | | | | |
| 8. The government effectively monitors the correct use of GE in the medical, agricultural and other sectors. | | | | | |
| 9. I think the additives in food are not harmful to my health. | | | | | |
| 10. The risks associated with GM food (if any) can be avoided. | | | | | |
| 11. When humans interfere with nature, disastrous consequences result. | | | | | |
| 12. Among the risks we presently face, those impacting food safety are very important. | | | | | |
| 13. If something went wrong with GM food, it would be a global disaster. | | | | | |
| 14. The government should spend more money to increase food safety. | | | | | |
| 15. Humans are harshly abusing the environment. | | | | | |
| 16. Pesticides and fertilizers are dangerous to our environment. | | | | | |
| 17. We can only eradicate the diseases and pests that attack crops by using GM technology. | | | | | |
| 18. Harmful environmental effects of GM crops are likely to appear in the distant future. | | | | | |
| 19. Harmful human health effects of GM foods are likely to appear in the distant future. | | | | | |
| 20. Even though GM food may have advantages, it is basically against nature. | | | | | |
| 21. Eating GM food would harm me and my family. | | | | | |
| 22. GM technology should not be used even for medicinal purposes. | | | | | |

2C: Awareness of Institutions and Organisations

There are a number of institutions in Uganda responsible for regulating, distribution, sale and consumption of food, beverages and planting materials (seed). In the table below, we have listed several of them and we would like you to let us know: First, whether you have heard or aware of them. Second, for those you are aware of, how do you think about their willingness to control the effects of the listed items in the table?

| Institutions | Do you know or heard of<br>1. Yes<br>2. No | Do you have confidence that the named institution can control production of food or crops that could be harmful to people (Trust not produce)?<br>1. Yes<br>2. No<br>3. Don't know | Do you have confidence that the named institution can prevent harmful products to be sold in shops, supermarkets and restaurants (Trust not sell)?<br>1. Yes<br>2. No<br>3. Don't know | Do you have confidence that the named institution can control release of crops that could be harmful to the environment (Trust not release)?<br>1. Yes<br>2. No<br>3. Don't know |
|---|---|---|---|---|
| Local leaders in the area | | | | |
| Extension workers in the district | | | | |
| National Agricultural Research Organisation | | | | |
| Uganda National Farmers' Federation | | | | |
| National Agricultural Advisory Services | | | | |
| Uganda National Bureau of Standards | | | | |
| Uganda Revenue Authority | | | | |
| University Scientists | | | | |
| Food Processors | | | | |
| Ministry of Trade | | | | |
| Ministry of Agriculture Animal Industry and Fisheries | | | | |
| National Environment management Authority | | | | |
| Politicians (ministers and MPs) | | | | |
| Non-Government Organisations | | | | |
| Uganda National Council of Science and Technology | | | | |
| Cooperatives | | | | |
| Uganda Trader Associations | | | | |
| Consumer Education Trust | | | | |
| AGT (private firm selling tissue culture planting materials) | | | | |

2 D: Knowledge about pest/diseases for banana and market participation

| | | | | | | |
|---|---|---|---|---|---|---|
| 1 | Does your household grow banana(If no, go to question 3) | 1= Yes | | | 0=No | |
| 2 | How many acres do you own? | | | | | |
| 3 | Do you have (know) any banana related diseases and pests which would affect the Production of banana in general and quality of banana as food? (If no, go to question 5) | Production<br><br>1= Yes<br><br>0= No | | | Quality<br><br>1= Yes<br><br>0=No | |
| 4 | If yes, could you please mention them?<br><br>1= Black sigatoka<br>2= Fusarium wilt<br>3= Bacterial wilt<br>4= Weevils<br>5=Nematodes<br>6= Others (specify) | Production | | | Quality | |
| | | 1. | | | 1. | |
| | | 2. | | | 2. | |
| | | 3. | | | 3. | |
| | | 4. | | | 4. | |
| | | 5. | | | 5. | |
| | | 6. | | | 6. | |
| 5 | Do you sell some of your banana (if NO to question 1, skip and proceed to question 7) | 1= Yes | | | 0=No | |
| 6 | How much did you earn last year (2006) in UGX? | July through December, 2006 | | | January through June, 2007 | |
| | | | | | | |
| 7 | Do you buy banana? | 1= Yes | | | 0=No | |
| 8 | If yes, how often do you buy? | 1=Daily | 2=Weekly | 3=Bimonthly | 4=Monthly | 5=Other (specify) |
| 9 | On average how much do you spend per shopping (UGX) for banana? | | | | | |

## Part 3. Imaginary shopping/Choice experiment

Please Read the Instructions carefully before making your decisions.

We would like you to imagine the following scenarios:

You are out of banana and you're shopping to restock for this (next) week. Imagine that there are **ONLY** two banana types available to you this week. Both banana types are new (A and B) on the market and they all have good taste, soft texture and yellow colour after cooking.

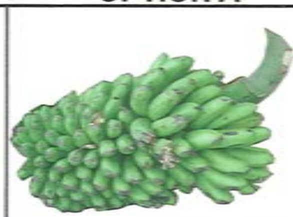
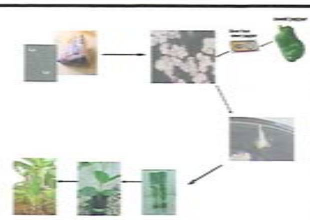
We are going to show you a number of scenarios (choice sets) and all you have to do is to choose the one you would more prefer to buy for you and your family. Alternatively, you would choose not to buy any banana of the two options and opt for your traditional variety.

**Attributes, their definitions, and levels for choice sets**

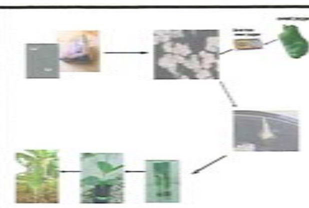
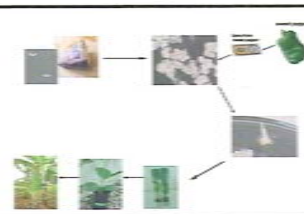
| Attributes | Definition | Attribute levels |
|---|---|---|
| Bunch size | The average banana bunch weight in kilograms at harvest categorized into small, medium and large. | 5 to 15 (small)<br>16 to 25 (medium)<br>26+ (large) |
| Extra Benefit | The estimated extra monetary benefit per hectare per year in Uganda shillings (UGX.), which would be accrued to the farmer if a gene is inserted in cooking banana planting materials in order to improve resistance to pests and disease | 0 (none)<br>60,000 (medium)<br>120,000 (large) |
| Technology | The technology used to produce the banana planting material | Tissue Culture + Traditional<br>Tissue Culture + GM |
| Price | Hypothetical change in price of a bunch of banana (%) | -30, -15, 0 +15, +30 , +40 |

**Two samples of the choice sets presented to respondents (Visual Aids)**

**SET 9**

| ATTRIBUTES | OPTION A | OPTION B | OPTION C |
|---|---|---|---|
| BUNCH SIZE |  |  | Neither A nor B, I prefer my own traditonal variety (i.e. Mostly small bunch size at no price change) |
| EXTRA BENEFIT |  120000/= |  60000/= | |
| TECHNOLOGY |  |  | |
| PRICE CHANGE | 30% ↑ | 15% ↑ | |

**SET 12**

| ATTRIBUTES | OPTION A | OPTION B | OPTION C |
|---|---|---|---|
| BUNCH SIZE |  |  | Neither A nor B, I prefer my own traditonal variety (i.e. Mostly small bunch size at no price change) |
| EXTRA BENEFIT |  60000/= |  120000/= | |
| TECHNOLOGY |  |  | |
| PRICE CHANGE | 30% ↓ | 15% ↑ | |

3 A: 16 Choice sets

Set 1

| ***Attribute*** | ***Option A*** | ***Option B*** | ***Option C*** |
|---|---|---|---|
| Bunch size (Kg) | 16-25 | 5-15 | Neither A nor B, I prefer my own traditional variety |
| Extra benefit to farmer per hectare (UGX) | 0 | 0 | |
| Technology | Tissue culture +GM | Tissue culture + traditional | |
| Price (% change) | 40 | 0 | |
| Indicate your choice by a tick in any one box | ☐ | ☐ | ☐ |

Set 2

| ***Attribute*** | ***Option A*** | ***Option B*** | ***Option C*** |
|---|---|---|---|
| Bunch size (Kg) | 16-25 | 26+ | Neither A nor B, I prefer my own traditional variety |
| Extra benefit to farmer per hectare (UGX) | 0 | 60000 | |
| Technology | Tissue culture +GM | Tissue culture +GM | |
| Price (% change) | 0 | -15 | |
| Indicate your choice by a tick in any one box | ☐ | ☐ | ☐ |

Set 3

| ***Attribute*** | ***Option A*** | ***Option B*** | ***Option C*** |
|---|---|---|---|
| Bunch size (Kg) | 5-15 | 16-25 | Neither A nor B, I prefer my own traditional variety |
| Extra benefit to farmer per hectare (UGX.) | 0 | 120000 | |
| Technology | Tissue culture +GM | Tissue culture +GM | |
| Price (% change) | 0 | 30 | |
| Indicate your choice by a tick in any one box | ☐ | ☐ | ☐ |

Set 4

| ***Attribute*** | ***Option A*** | ***Option B*** | ***Option C*** |
|---|---|---|---|
| Bunch size (Kg) | 5-15 | 16-25 | Neither A nor B, I prefer my own traditional variety |
| Extra benefit to farmer per hectare (UGX.) | 0 | 60000 | |
| Technology | Tissue culture +GM | Tissue culture +GM | |
| Price (% change) | -15 | 15 | |
| Indicate your choice by a tick in any one box | ☐ | ☐ | ☐ |

Set 5

| *Attribute* | *Option A* | *Option B* | *Option C* |
|---|---|---|---|
| Bunch size (Kg) | 16-25 | 5-15 | Neither A nor B, I prefer my own traditional variety |
| Extra benefit to farmer per hectare (UGX.) | 120000 | 0 | |
| Technology | Tissue culture +GM | Tissue culture +GM | |
| Price (% change) | -15 | 30 | |
| Indicate your choice by a tick in any one box | ☐ | ☐ | ☐ |

Set 6

| *Attribute* | *Option A* | *Option B* | *Option C* |
|---|---|---|---|
| Bunch size (Kg) | 5-15 | 16-25 | Neither A nor B, I prefer my own traditional variety |
| Extra benefit to farmer per hectare (UGX.) | 60000 | 0 | |
| Technology | Tissue culture +GM | Tissue culture +GM | |
| Price (% change) | -15 | 15 | |
| Indicate your choice by a tick in any one box | ☐ | ☐ | ☐ |

Set 7

| *Attribute* | *Option A* | *Option B* | *Option C* |
|---|---|---|---|
| Bunch size (Kg) | 5-15 | 26+ | Neither A nor B, I prefer my own traditional variety |
| Extra benefit to farmer per hectare (UGX.) | 0 | 120000 | |
| Technology | Tissue culture + traditional | Tissue culture +GM | |
| Price (% change) | 15 | 0 | |
| Indicate your choice by a tick in any one box | ☐ | ☐ | ☐ |

Set 8

| *Attribute* | *Option A* | *Option B* | *Option C* |
|---|---|---|---|
| Bunch size (Kg) | 5-15 | 16-25 | Neither A nor B, I prefer my own traditional variety |
| Extra benefit to farmer per hectare (UGX.) | 120000 | 0 | |
| Technology | Tissue culture +GM | Tissue culture +GM | |
| Price (% change) | -30 | -15 | |
| Indicate your choice by a tick in any one box | ☐ | ☐ | ☐ |

Set 9

| *Attribute* | *Option A* | *Option B* | *Option C* |
|---|---|---|---|
| Bunch size (Kg) | 26+ | 5-15 | Neither A nor B, I prefer my own traditional variety |
| Extra benefit to farmer per hectare (UGX.) | 120000 | 60000 | |
| Technology | Tissue culture +GM | Tissue culture +GM | |
| Price (% change) | 30 | 15 | |
| Indicate your choice by a tick in any one box | ☐ | ☐ | ☐ |

Set 10

| *Attribute* | *Option A* | *Option B* | *Option C* |
|---|---|---|---|
| Bunch size (Kg) | 5-15 | 26+ | Neither A nor B, I prefer my own traditional variety |
| Extra benefit to farmer per hectare (UGX.) | 0 | 60000 | |
| Technology | Tissue culture + traditional | Tissue culture +GM | |
| Price (% change) | 30 | 0 | |
| Indicate your choice by a tick in any one box | ☐ | ☐ | ☐ |

Set 11

| *Attribute* | *Option A* | *Option B* | *Option C* |
|---|---|---|---|
| Bunch size (Kg) | 26+ | 5-15 | Neither A nor B, I prefer my own traditional variety |
| Extra benefit to farmer per hectare (UGX.) | 0 | 120000 | |
| Technology | Tissue culture + traditional | Tissue culture +GM | |
| Price (% change) | -30 | 40 | |
| Indicate your choice by a tick in any one box | ☐ | ☐ | ☐ |

Set 12

| *Attribute* | *Option A* | *Option B* | *Option C* |
|---|---|---|---|
| Bunch size (Kg) | 16-25 | 26+ | Neither A nor B, I prefer my own traditional variety |
| Extra benefit to farmer per hectare (UGX.) | 60000 | 120000 | |
| Technology | Tissue culture +GM | Tissue culture +GM | |
| Price (% change) | -30 | 15 | |
| Indicate your choice by a tick in any one box | ☐ | ☐ | ☐ |

Set 13

| *Attribute* | *Option A* | *Option B* | *Option C* |
|---|---|---|---|
| Bunch size (Kg) | 26+ | 16-25 | Neither A nor B, I prefer my own traditional variety |
| Extra benefit to farmer per hectare (UGX.) | 0 | 0 | |
| Technology | Tissue culture +GM | Tissue culture + traditional | |
| Price (% change) | -30 | 0 | |
| Indicate your choice by a tick in any one box | ☐ | ☐ | ☐ |

Set 14

| *Attribute* | *Option A* | *Option B* | *Option C* |
|---|---|---|---|
| Bunch size (Kg) | 16-25 | 26+ | Neither A nor B, I prefer my own traditional variety |
| Extra benefit to farmer per hectare (UGX) | 60000 | 120000 | |
| Technology | Tissue culture +GM | Tissue culture +GM | |
| Price (% change) | 30 | 15 | |
| Indicate your choice by a tick in any one box | ☐ | ☐ | ☐ |

Set 15

| *Attribute* | *Option A* | *Option B* | *Option C* |
|---|---|---|---|
| Bunch size (Kg) | 5-15 | 16-25 | Neither A nor B, I prefer my own traditional variety |
| Extra benefit to farmer per hectare (UGX.) | 60000 | 0 | |
| Technology | Tissue culture +GM | Tissue culture + traditional | |
| Price (% change) | 40 | -15 | |
| Indicate your choice by a tick in any one box | ☐ | ☐ | ☐ |

Set 16

| *Attribute* | *Option A* | *Option B* | *Option C* |
|---|---|---|---|
| Bunch size (Kg) | 16-25 | 26+ | Neither A nor B, I prefer my own traditional variety |
| Extra benefit to farmer per hectare (UGX.) | 120000 | 60000 | |
| Technology | Tissue culture +GM | Tissue culture +GM | |
| Price (% change) | -30 | 30 | |
| Indicate your choice by a tick in any one box | ☐ | ☐ | ☐ |

3 B: Which of the following attributes prompted you most to choose either option A or option B?

Please indicate your strength of agreement or disagreement for each of the following statements from 1- 5

| | **Is the most important attribute when choosing option A and B above** | Strongly disagree (1) | disagree (2) | neither disagree nor agree (3) | agree (4) | Strongly agree (5) |
|---|---|---|---|---|---|---|
| 1 | Bunch size | | | | | |
| 2 | Extra benefit farmer receives per hectare if s/he plants GM banana | | | | | |
| 3 | Technology | | | | | |
| 4 | Price | | | | | |

3C: If you opted for your own traditional varieties (option C) in one of the choice sets, please list down the characteristics of your own traditional varieties?

| | **Attribute levels (characteristics) of own traditional variety** |
|---|---|
| **1** | |
| **2** | |
| **3** | |
| **4** | |
| **5** | |
| **6** | |

# References


Agricultural Science and Technology Indicators, ASTI. 2002. ASTI Country Brief No. 1. http://www.asti.cgiar.org/uganda, accessed September 28, 2009.

Andrews, R.L., and I.S. Currim. 2003. A Comparison of Segment Retention Criteria for Finite Mixture Logit Models. *Journal of Marketing Research* 40(2): 235-243.

Arrow, K.J., and A.C. Fisher. 1974. Environmental Preservation, Uncertainty and Irreversibility. *Quarterly Journal of Economics* 88:312-319.

Bachelier, L. 1900. *Theory of speculation.* Paris: Gauthier-Villars. Translated by A.J. Boness and Reprinted in P. Cootner, *The Random Character of Stock Market Prices.* Cambridge: MIT Press, 1964.

Bagamba, F. 2007. Market Access and Agricultural Production: The Case of Banana Production in Uganda. Doctoral thesis, Wageningen University, The Netherlands.

Bateman, I.J., Carson, R.T., Day, B., Hanemann, W.M., Hanley, N., Hett, T., Jones-Lee, M., Loomes, G., Mourato, S., Ozdemiroglu, E., Pearce, D.W., Sugden, R. and S. Swanson. 2003. *Guidelines for the Use of Stated Preference Techniques for the Valuation of Preferences for Non-market Goods*. Cheltenham: Edward Elgar.

Beckmann, V., Soregaroli, C., and J. Wesseler. 2006a. Governing the Co-existence of GM Crops: Ex-ante Regulation and Ex-post Liability Under Uncertainty and Irreversibility. Institutional Change in Agriculture and Natural Resources (ICAR) Discussion Paper 12/2006, Humboldt University, Berlin.

Beckmann, V., Soregaroli, C., and J. Wesseler. 2006b. Co-existence Rules and Regulations in the European Union. *American Journal of Agricultural Economics* 88 (5): 1193–99.

Ben-Akiva, M., and J. Swait. 1986. The Akaike Likelihood Ratio Index. *Transportation Science* 20 (2):133-136.

Bennett, J.J., and R.K. Blamey. 2001. *The Choice of Modelling Approach to Environmental Valuation.* Cheltenham: Edward Elgar.

Bennett, J.J., Van Bueren, M., and S.M. Whitten. 2004. Estimating Society's Willingness to Pay to Maintain Viable Rural Communities. *Australian Journal of Agricultural and Resource Economics* 48 (3): 487–512.

Bergmann, A., Hanley, N., and R. Wright. 2006. Valuing the Attributes of Renewable Energy Investments. *Energy Policy* 34(9): 1004–1014.

Bergmann, A., Colombo, S., and N. Hanley. 2008. Rural Versus Urban Preferences for Renewable Energy Developments. *Ecological Economics* 65:616-625.

Bernstein, P. L. 1992. *Capital Ideas: The Improbable Origins of Modern Wall Street.* New York: Free Press.

Beyer, J.C., Norton, G.W., and J.B. Falck-Zepeda. 2008. The Cost of Biotechnology Regulation in the Philippines. Paper Presented at the 2008 Annual Meeting of the American Association of Agricultural Economics, Orlando, Florida. Available at AGECON Search on the World Wide Web: http://purl.umn.edu/6507.

Birol, E., Villalba, E.R., and M. Smale. 2009. Farmer Preferences for *Milpa* Diversity and Genetically Modified Maize in Mexico: A Latent Class Approach. *Environment and Development Economics* 14(4): 521-540.

Birol, E., Villalba, E.R., and M. Smale. 2007. Farmer Preferences for *Milpa* Diversity and Genetically Modified Maize in Mexico: A Latent Class Approach. Discussion paper 726, International Food Policy Research Institute, Washington, D.C.

Boxall, P.C., and W.L. Adamowicz. 2002. Understanding Heterogeneous Preferences in Random Utility Models: A Latent Class Approach. *Environmental and Resource Economics* 23: 421-446.

Breffle, W., and E. Morey. 2000. Investigating Preference Heterogeneity in a Repeated Discrete-Choice Recreation Demand Model of Atlantic Salmon Fishing. *Marine Resource Economics* 15: 1-20.

Brenner, C. 2004. Telling Transgenic Technology Tales: Lessons from the Agricultural Biotechnology Support Project (ABSP) Experience. ISAAA (International Service for the Acquisition of Agri-biotech Applications) Brief 31, Ithaca, N.Y.

Brookes, G., and P. Barfoot. 2009. Global Impact of Biotech Crops: Income and Production Effects, 1996-2007. *AgBioForum* 12(2): 184-208.

Campbell, J.Y., Lo, A.W., and A.C. MacKinlay. 1997. *The Econometrics of Financial Markets*. Princeton, N.J.: Princeton University Press.

Carlssion, F., Frykoblom, P., and C. Liljenstolpe. 2003. Valuing Wetland Attributes: an Application of Choice Experiments. *Ecological Economics* 47:95-103.

Chen, W. S., Rickertsen, K., Tsuboi, N., and T.-T. Fu. 2002. Consumer Acceptance and Willingness to Pay for Genetically Modified Vegetable Oil and Salmon: A Multiple-Country Assessment. *AgBioForum* 5(3): 105-112.

Clark, N., Mugabe, J., and J. Smith. 2005. *Governing Agricultural Biotechnology in Africa: Building Public Confidence and Capacity for Policy-Making*. Nairobi, Kenya: ACS Press.

Clarke, T. 2003. Banana Lab Opens in Uganda: Genetic Modification of Clonal Crop could soon Follow. *Nature News,* August 22. http://www.bioedonline.org/news/news.cfm?art=430.

Colombo S., Hanley, N., and J. Louviere. 2009. Modeling Preference Heterogeneity in Stated Choice Data: an Analysis for Public Goods Generated by Agriculture. *Agricultural Economics* 40 (3): 307-322.

Colombo, S., Hanley, N., and J. Calatrava-Requena. 2005. Designing Policy for Reducing the Off-farm Effects of Soil Erosion Using Choice Experiments. *Journal of Agricultural Economics* 56(1): 81–95.

Cox, D., and H. Miller. 1965. *The Theory of Stochastic Processes*. London: Chapman and Hall.

Craenen, K. 1998. *Black Sigatoka Disease of Banana and Plantain: A Reference Manual.* Ibadan: International Institute of Tropical Agriculture.

Curtis, K.R., McCluskey, J.J., and T.I. Wahl. 2004. Consumer Acceptance of Genetically Modified Food Products in the Developing World*.* *AgBioForum* 7(1&2): 70-75

Dannenberg, A., Scatasta, S., and B. Sturm. 2009. Keine Chance für Genetisch Veränderte Lebensmittel in Deutschland? Eine Experimentelle Analyse von Zahlungsbereitschaften. Perspektiven der Wirtschaftspolitik 10:214-234.

Demont, M., Wesseler, J., and E. Tollens. 2004. Biodiversity versus Transgenic Sugar Beet: The One Euro Question. *European Review of Agricultural Economics* 31 (1): 1–18.

de Vries, J., and G. Toenniessen. 2001. *Securing the Harvest: Biotechnology, Breeding and Seed Systems for African Crops*. Wallingford, U.K.: CAB International.

Dixit, A., and R.S. Pindyck. 1994. *Investment under Uncertainty.* Princeton, N.J.: Princeton University Press.

Edmeades, S. 2003. Variety Choice and Attribute Trade-offs within the Framework of Agricultural Household Models: The Case of Bananas in Uganda. PhD Dissertation, North Carolina State University, Raleigh.

Edmeades, S. 2007. A Hedonic Approach to Estimating the Supply of Variety Attributes of a Subsistence Crop. *Agricultural Economics* 37 (1): 19–28.

Edmeades, S., and M. Smale. 2006. A Trait-Based Model of the Potential Demand for a Genetically Engineered Food Crop in a Developing Economy. *Agricultural Economics* 35: 351–361.

Eicher, C.K., Maredia, K., and I. Sithole-Niang. 2006. Crop Biotechnology and the African Farmer. *Food Policy* 31(6): 504-527.

Einsele, A. 2007. The Gap between Science and Perception: The Case of Plant Biotechnology in Europe. *Advances in Biochemical Engineering/Biotechnology* 107: 1-11.

European Commission, 2006. Risk Issues. *Eurobarometer* 238.

Fabrigar, L.R., MacCallum, R.C., Wegener, D.T., and E.J. Strahan. 1999. Evaluating the Use of Explanatory Analysis in Psychological Research. *Psychological Methods* 4: 272-299.

Falck-Zepeda, J.B. 2006. Coexistence, Genetically Modified Biotechnologies, and Biosafety: Implications for Developing Countries. *American Journal of Agricultural Economics* 88 (5): 1200–08.

Falck-Zepeda, J.B. 2009. Socio-economic Considerations, Article 26.1 of the Cartagena Protocol on Biosafety: What are the Issues and What is at Stake? *AgBioForum* 12(1): 90-107

Feder, G., Just, R.E., and D. Zilberman. 1985. Adoption of Agricultural Innovations in Developing Countries: A Survey. *Economic Development and Cultural Change* 33: 255–98.

Food and Agriculture Organization (FAO). 2001. Biotechnology and Banana Production. Committee on Commodity Problems Intergovernmental Group on Bananas and Tropical Fruits, San Jose, Costa Rica.

Food and Agriculture Organization (FAO). 2009. How to Feed the World 2050. The Special Challenge for Sub Saharan Africa. High Expert Forum, October 12-13, Rome, Italy. http://www.fao.org/fileadmin/templates/wsfs/docs/Issues_papers/HLEF2050_Africa.pdf. Accessed 9 October 2009.

Freeman III, A.M., 2003. *The measurement of Environmental and Resource Values: Theory and Methods*, 2nd Edition. Washington, D.C.: Resources for the Future Press.

Frewer, L., Lassen J., Kettlitz B., Scholderer, J., Beekman V., and K.G. Berdal. 2004. Societal Aspects of Genetically Modified Foods. *Food and Chemical Toxicology* 42: 1181-1193.

Garrod, G.D., Scarpa, R., and K.G. Willis. 2002. Estimating the Benefits of Traffic Calming on Through Routes: A Choice Experiment Approach. *Journal of Transport Economics and Policy* 36(2): 211–231.

Gaskell, G., Allansdottir, A., Allum, N., Corchero, C., Fischler, C., Hampel, J., Jackson, J., Kronberger, N., Mejlgaard, N., Revuelta, G., Schreiner, C., Stares, S., Torgersen, H., and W. Wagner. 2006. Europeans and Biotechnology in 2005: Patterns and Trends. Eurobarometer 64.3. The European Commission, Brussels.

Gold, C.S. 1998. Banana weevil: Ecology Pest Status and Prospects for Integrated Control with Emphasis on East Africa. In Saini, S.K. (ed), *Proceedings of a Symposium on Biological Control in Tropical Habitats: Third International Conference on Tropical*

*Entomology,* pp. 49–74. Nairobi: International Centre of Insect Physiology and Ecology(ICIPE).

Gold, C.S. 2000. Biology and Integrated Pest Management of Banana Weevil, *Cosmopolites sordidus* (Germar). In Molina, A.B., Roa, V.N., and M.A.G. Maghuyop (eds), *Advancing Banana and Plantain R&D in Asia and the Pacific,* vol. 10, pp. 28–33. International Network for the Improvement of Banana and Plantain - Asia and the Pacific Network (INIBAP-ASPNET).

Gold, C.S., Night, G., Abera, A., and P.R. Speijer. 1998. Hot-water Treatment for the Control of the Banana Weevil, *Cosmopolites sordidus* Germar (*Coleoptera: Curculionidae*), in Uganda. *African Entomology* 6 (2): 215–21.

Gold, C.S., Pena, J.E., and E.B. Karamura. 2001. Biology and Integrated Pest Management for the Banana Weevil, *Cosmopolites sordidus* (Germar) (*Coleoptera: Curculionidae*). *Integrated Pest Management Reviews* 6 (2): 79–155.

GOU (Government of Uganda). 2009. Draft Estimates of Revenue and Expenditure (recurrent and Development) FY 2009/10. http://www.finance.go.ug/docs/Draft%20Budget%20 20Estimates%20FY2009.

Greene, W., and D. Hensher. 2003. A latent Class Model for Discrete Choice Analysis: Contrasts with Mixed Logit. *Transportation Research, Part B* 37: 681–98.

Greene, W.H. 1997. *Econometric Analysis,* Third Edition. New York: Prentice Hall.

Greene, W.H. 2008. *Econometric analysis*. Sixth Edition. New York: Prentice Hall.

Griliches, Z. 1957. Hybrid Corn: An exploration in the Economics of Technological Change. *Econometrica* 25 (4): 501-522.

Hausman J.A., and D. McFadden. 1984. Specification Tests for the Multinomial Logit Model. *Econometrica* 52: 1219-1240.

Henry, C. 1974. Investment Decision under Uncertainty: The Irreversibility Effect. *American Economic Review* 64: 1006–12.

Hensher, D., Rose, J., and W. Greene. 2005. *Applied Choice Analysis: A Primer*. Cambridge: Cambridge University Press.

Herring, R.J. 2008. Opposition to Transgenic Technologies: Ideology, Interests and Collective Action Frames. *Nature Reviews Genetics* 9: 458-463.

Hu, W., Hünnemeyer, A., Veeman, M., Adamowicz, W.L., and L. Srivastava. 2004. Trading off Health, Environmental and Genetic Modification Attributes in Food. *European Review of Agricultural Economics* 31: 389-408.

Jaffe, G. 2006. Comparative Analysis of the National Biosafety Regulatory Systems in East Africa. EPTD Discussion Paper 146, International Food Policy Research Institute, Washington, D.C.

———.2005. Implementing the Cartagena Biosafety Protocol through National Biosafety Regulatory Systems: An Analysis of Key Unresolved Issues. *Journal of Public Affairs* 5:299-311.

James, C. 2008. Global Status of Commercialized Biotech/GM crops: 2008. ISAAA Brief No. 39. ISAAA: Ithaca, NY.

Johnson, F.R., Kanninen, B., Bingham, M., and S. Özdemir. 2007. Experimental Design for Stated Choice Studies. In Kanninen, B. J. (ed), *Valuing Environmental Amenities Using Stated Choice Studies*: *A Common Sense Approach to Theory and Practice,* pp 159-202. Dordrecht: Springer.

Just, R.E., Alston, J.M., and D. Zilberman. 2006. What have We Learned and Where Do We Go from Here? In Just, R.E., Alston, J.M., and D. Zilberman (eds), *Regulating Agricultural Biotechnology: Economics and Policy,* pp. 701–22. New York: Springer.

Just, R.E., Hueth, D.L., and A. Schmitz. 2004. *The Welfare Economics of Public Policy: A Practical Approach to Project and Policy Evaluation.* Cheltenham: Edward Edgar.

Kalaitzandonakes, N., Alston, J., and K. Bradford. 2007. Compliance Costs for Regulatory Approval of New Biotech Crops. *Nature Biotechnology* 25(5): 509-11.

Kaldor, N. 1939. Welfare Propositions of Economics and Interpersonal Comparisons of Utility. *The Economic Journal* 49(195): 549-552.

Kalyebara, M.R., Ragama, P.E., Kagezi, G.H., Kubiriba, J., Bagamba, F., Nankinga, C.K., and W.K. Tushemereirwe. 2006. Economic Importance of the Banana Bacterial Wilt in Uganda. *African Crop Science Journal* 14 (2): 93–105.

Kalyebara, M.R., Wood, S., and P.N. Abodi. 2007. Assessing the Potential Impact of Selected Technologies on the Banana Industry in Uganda. In Smale, M., and W.K. Tushemereirwe (eds), *An Economic Assessment of Banana Genetic Improvement and Innovation in the Lake Victoria Region of Uganda and Tanzania*. Research Report no. 155, pp.141-153. Washington, D.C.: International Food Policy Research Institute.

Karamura, D.A. 1998. Numerical Taxonomic Studies of the East African Highland Bananas (Musa AAA–East Africa) in Uganda. Doctoral thesis, University of Reading, United Kingdom.

Karembu, M., Nguthi, F., and H. Ismail. 2009. Biotech Crops in Africa: *The Final Frontier*. Nairobi, Kenya: ISAAA AfriCenter.

Kendall, H.W., Beachy, R., Eisner, T., Gould, F., Herdt, R., Raven, P. H., Schell, J.S., and M. S. Swaminathan. 1995. Bioengineering of Crops. Report of the World Bank Panel on Transgenic Crops. Washington, D.C.: World Bank.

Kiggundu, A., Tushemereirwe, W., Arinaitwe, G., Talengera, G., Namukwaya, B., Changa, C. M., Lamwaka, P., Fungo, R., and J. Mukiibi. 2008. Novel Biotechnological Approaches for the Improvement of East African Highland Banana Productivity and Utilization. Paper Presented at the Banana Conference, Held 5-9 October 2008 in Mombasa, Kenya. http://www.banana2008.com/cms/posters/kiggundu.pdf.

Kikulwe, E., Wesseler, J., and J. Falck-Zepeda. 2008. Introducing a Genetically Modified Banana in Uganda: Social Benefits, Costs, and Consumer Perceptions. Discussion Paper 767. Washington, D.C.: International Food Policy Research Institute.

Kikulwe, M.E., Nowakunda, K., Byabachwezi, M.S.R., Nkuba, J.M., Namaganda, J., Talengera, D., Katungi, E., and W.K. Tushemereirwe. 2007. Development and dissemination of improved banana cultivars and management practices in Uganda and Tanzania. In: Smale, M., and W.K. Tushemereirwe (Eds.), *An economic assessment of banana genetic improvement and innovation in the Lake Victoria region of Uganda and Tanzania*. Research report no. 155, pp 37-48. Washington, D.C.: International Food Policy Research Institute.

Kim, H-S., and K. Kim. 2004. A Multi-country Assessment of Consumer Attitudes of Genetically Modified Foods and the Implications for New Labeling System**.** Paper presented at the American Agricultural Economics Association Annual Meeting, Held 1-4 August 2004 in Denver, Colorado, USA. http://ageconsearch.umn.edu/bitstream /19989/1/sp04ki04.pdf.

Kimenju, S.C., and H. De Groote. 2008. Consumer Willingness to Pay for Genetically Modified Food in Kenya. *Agricultural Economics* 38: 35-46.

Knight, J.A., Mather, D.W., Holdsworth, D.K., and D.F. Ermen. 2007. Acceptances of GM Food: An Experiment in Six Countries. *Nature Biotechnology* 25(5): 507-508.

Kontoleon, A., 2003. Essays on Non-market Valuation of Environmental Resources: Policy and Technical Explorations, PhD Thesis, University College London, University of London.

Kontoleon, A., and M. Yabe. 2006. Market Segmentation Analysis of Preferences for GM Derived Animal Foods in the UK. *Journal of Agricultural & Food Industrial Organization* 4. no.1(January): Article 8. http://www.bepress.com/jafio/vol4/iss1/art8 (accessed July 15, 2007).

Krishna, V.V., and M. Qaim. 2008. Consumer Attitudes toward GM Food and Pesticide Residues in India. *Review of Agricultural Economics* 30:233-251.

Kuhfeld, W.F. 2004. Marketing Research Methods in SAS: Experimental Design, Choice, Conjoint, and Graphical Techniques." SAS Document TS-694. http://support.sas.com/ techsup/technote/ts694.pdf.

Lancaster, K. 1966. A New Approach to Consumer Theory. *Journal of Political Economy* 74:132-157.

Li, Q., Curtis, K.R., McCluskey, J.J., and T.I. Wahl. 2002. Consumer Attitudes toward Genetically Modified Foods in Beijing, China. *AgBioForum* 5(4):145-152.

Lin, W., Somwaru, A., Tuan, F., Huang, J., and J. Bai. 2006. Consumers' Willingness to Pay for Biotech Foods in China: A Contingent Valuation Approach. *AgBioForum* 9(3):166-179.

List, J., and C. Gallet. 2001. What Experimental Protocol Influence Disparities between Actual and Hypothetical Stated Values?" *Environmental and Resource Economics* 20 (3): 241-254.

List J., Sinha P., and M.Taylor. 2006. Using Choice Experiments to Value Non-market Goods and Services: Evidence from Field Experiments. *Advances in Economic Analysis and Policy* 6 (2): 1-37.

Loureiro, M.L., and M. Bugbee. 2005. Enhanced GM Foods: Are Consumers Ready to Pay for the Potential Benefits of Biotechnology? *Journal of Consumer Affairs* 39 (1): 52-70.

Louviere, J.J., Hensher, D.A., Swait, J.D., and W.L. Adamowicz. 2000. *Stated Choice Methods: Analysis and Applications*, Cambridge University Press, Cambridge.

Luce, D., 1959. *Individual Choice Behaviour*. New York: John Wiley.

Maddala, G.S. 1999. *Limited Dependent and Qualitative Variables in Econometrics.* Cambridge: Cambridge University Press.

Maddala, G.S. 2001. *Introduction to Econometrics,* Third edition. Saddle River (NJ): Prentice Hall.

Marshall, A. 1930. *Principles of Economics*. London: Macmillan.

McCluskey, J.J., Grimsrud, K.M., Ouchi, H., and T.I. Wahl. 2003. Consumer Response to Genetically Modified Food Products in Japan. *Agricultural and Resource Economics Review* 32(2):222-231.

McFadden, D. 1974. Conditional Logit Analysis of Qualitative Choice Behavior. In *Frontiers in Econometrics*, ed. P. Zarembka. New York: Academic Press.

McFadden, D., and K. Train. 2000. Mixed MNL Models of Discrete Response. *Journal of Applied Economics* 56: 162-175.

Mitthöfer, D. 2005. Economics of Indigenous Fruit Tree Crops in Zimbabawe. PhD Thesis.

Faculty of Economics, Hannover University, Germany.

Modgil, M., Mahajan K., Chakrabarti1, S.K., Sharma, D.R., and R.C. Sobti. 2005. Molecular Analysis of Genetic Stability in Micropropagated Apple Rootstock MM106. *Scientia Horticulturae* 104: 151–60.

Morey, E., and K. Rossmann. 2003. Using Stated-Preference Questions to Investigate Variations in Willingness to Pay for Preserving Marble Monuments: Classic Heterogeneity, Random Parameters, and Mixture Models. *Journal of Cultural Economics* 27**:** 215–229.

Morrison, M., Bennett, J., and R. Blamey. 1999. Valuing Improved Wetlands Quality Using Choice Modeling. *Water and Resource Research* 35:2805–2814.

Mucci, A., Hough, G., and C. Ziliani. 2004. Factors that Influence Purchase Intent and Perceptions of Genetically Modified Foods among Argentine Consumers. *Food Quality and Preference* 15: 559-567.

Navarro, M.J. 2008. *Bridging the Knowledge Divide: Experiences in Communicating Crop Biotechnology*. Metro Manira, Philippines: ISAAA SEAsiaCenter.

NARO (National Agricultural Research Organization). 2001. Multilocational Banana Germplasm Evaluation Trials. Third Report. Unpublished Manuscript, NARO, Entebbe, Uganda.

Nielsen, C.P., Thierfelder, K., and S. Robinson. 2001. Genetically Modified Foods, Trade, and Developing Countries. Trade and Macroeconomics Division. Discussion Paper 77. Washington, DC.: International Food Policy Research Institute.

Nowakunda, K. 2001. Determination of Consumer Acceptability of Iintroduced Bananas. Unpublished Master's Thesis, Makerere University, Uganda.

Nowakunda, K., Rubaihayo, P.R., Ameny, M.A., and W.K. Tushemereirwe. 2000. Consumer Acceptability of Introduced Bananas in Uganda. *InfoMusa* 9 (2): 22–25.

Othman, J., Bennett, J., and R. Blamey. 2004. Environmental Values and Resource Management Options: A choice Modelling Experience in Malaysia. *Environment and Development Economics* 9: 803–824.

Ouma, E., Abdulai, A., and A. Drucker. 2007. Measuring Heterogeneous References for Cattle Traits Among Cattle-Keeping Households in East Africa. *American Journal of Agricultural Economics* 89:1005-1019.

Owen, K., Louviere, J., and J. Clark. 2005. Impact of Genetic Engineering on Consumer Demand. Final Report for the Rural Industries Research and Development Corporation, RIRDC Publication No. 05/015. www.rirdc.gov.au/fullreports/index.htm.

Oxford Policy Management (OPM). 2005. Evaluation of the Plan for the Modernization of Agriculture: Main Report. http://www.pma.go.ug/pmauploads/Main%20PMA%20 evaluation%20final%20reportpdf.

Paarlberg, R. 2008. *Starved for Science: How Biotechnology is Being Kept Out of Africa*. Cambridge: Harvard University Press.

Portney, P.R. 1994. The Contingent Valuation Debate: Why Economists Should Care. *Journal of Economic Perspectives* 8:3–17.

Qaim, M. 1999. Assessing the Impact of Banana Biotechnology in Kenya. *ISAAA Briefs* No. 10. Ithaca, NY: ISAAA.

Qaim, M. 2009. The Economics of Genetically Modified Crops. *Annual Review of Resource Economics* 1: 3.1-3.29.

Revelt, D., and Train, K. 1998. Mixed logit with Repeated Choices: Households' Choice of Appliance Efficiency Level. *Review of Economics and Statistics* 53:647–657.

Rigby, D., and M. Burton. 2005. Preference Heterogeneity and GM Food in the UK. *European Review of Agricultural Economics* 32 (2): 269–88.

Rolfe, J., Bennett, J., and J. Louviere. 2000. Choice Modelling and its Potential Application to Tropical Rainforest Preservation. *Ecological Economics* 35 (2): 289-302.

Rolfe J.R., and Windle, J. 2005. Valuing Options for Reserve Water in the Fitzroy Basin. *The Australian Journal of Agricultural and Resource Economics* 49(1): 91-114.

Rubaihayo, P. R. 1991. Banana-based Cropping Systems Research: A Report on Rapid Appraisal Survey of Banana Production in Uganda. Research Bulletin 1. Department of Crop Science, Makerere University, Kampala, Uganda.

Rubaihayo, P. R., and C. Gold. 1993. Banana-based Cropping Systems Research: A Report on Rapid Appraisal Survey of Banana Production in Uganda. Research Bulletin 2. Department of Crop Science, Makerere University, Kampala, Uganda.

Ruto, E., Garrod, G., and R. Scarpa. 2008. Valuing Animal Genetic Resources: A Choice Modeling Application to Indigenous Cattle in Kenya. *Agricultural Economics* 38:89-98.

Saner, M. 2007. What is Public Involvement? Paper Presented During the High Level Policy Dialogue Workshop on Public Perception of Agricultural Biotechnology. Lima, Peru, October 4-5.

Scarpa, R., Drucker, A., Anderson, S., Ferraes-Ehuan, N., Gomez, V., Risopatron, C.R., and O. Rubio-Leonel. 2003. Valuing Animal Genetic Resources in Peasant Economies: The Case of the Box Keken Creole Pig in Yucatan. *Ecological Economics* 45(3):427-443.

Scatasta, S., Wesseler, J., and M. Demont. 2006. Irreversibility, Uncertainty, and the Adoption of Transgenic Crops: Experiences from Applications to Ht sugar Beet, Ht Corn, and Bt corn. In Just, R.E., Alston, J.M., and D. Zilberman (eds), *Regulating Agricultural Biotechnology: Economics and Policy,* pp. 327–52. New York: Springer.

Secretariat of the Convention on Biological Diversity. 2000. *Cartagena Protocol on Biosafety to the Convention on Biological Diversity: Text and Annexes.* Montreal: Secretariat of the Convention on Biological Diversity.

Smale, M., and W.K. Tushemereirwe, Eds. 2007. *An economic Assessment of Banana Genetic Improvement and Innovation in the Lake Victoria Region of Uganda and Tanzania.* Research report no. 155, pp 188. Washington, D.C.: International Food Policy Research Institute.

Smale, M., Zambrano, P., Gruère, G., Falck-Zepeda, J.B., Matuschke, I., Horna, D., Nagarajan, L., Yerramareddy, I., and H. Jones. 2009. *Measuring the Economic*

*Impacts of Transgenic Crops in Developing Agriculture during the First Decade: Approaches, Findings, and Future Directions.* Food Policy Review 10, pp. 107. Washington, D.C.: International Food Policy Research Institute.

Ssebuliba, R., Talengera, D., Makumbi, D., Namanya, P., Tenkouano, A., Tushemereirwe, W., and M. Pillay. 2006. Reproductive Efficiency and Breeding Potential of East African Highland (Musa AAA–EA) Bananas. *Field Crops Research* 95:250–55.

Ssebuliba, R.N. 2001. Fertility in East African Highland Bananas. Doctoral Thesis, Makerere University, Uganda.

Stover, R. H., and N. W. Simmonds. 1987. *Bananas.* 3rd ed. London: Longman.

Swait, J. R. 1994. A Structural Equation Model of Latent Segmentation and Product Choice for Cross-sectional Revealed Reference Choice Data. *Journal of Retailing and Consumer Services* 1: 77–89.

Swennen, R., and D.R. Vuylsteke. 1988. Bananas in Africa: Uses and Prospects for Improvement. In *Crop Genetic Resources for Africa.* Vol. 2. Proceedings of an International Conference, Ibadan, Nigeria.

Train, K.E. 1998. Recreation Demand Models with Taste Differences over People. *Land Economics* 74:230–239.

Tripathi, L. 2003. Genetic Engineering for Improvement of *Musa* Production in Africa. *African Journal of Biotechnology* 2 (12): 503–08.

Tushemereirwe, W.K., Kashaija, I., Tinzaara, W., Nankinga, C., and S. New. 2003. *Banana Production Manual: A Guide to Successful Banana Production in Uganda*. 2nd ed. Kampala: Makerere University Printery.

Tushemereirwe, W.K., Holderness, M., Gold, C.S., Karamura, E.B., and M. Deadman. 1996. Distribution and Importance of the Leafspot Complex on Highland Bananas in Uganda. *MusAfrica* 10:25.

Tushemereirwe, W., Kashaija, I.K., Tinzaara, W., Nankinga, C., and S.S. New. 2000. *Banana Production Manual: A Guide to Successful Banana Production.* National Agricultural

Research Organization and Agribusiness Development Centre - Investment in Developing Export Agriculture (ADC-IDEA).

Uganda Bureau of Statistics (UBOS). 2006a. *2002 Uganda Population and Housing Census: Main report.* http://www.ubos.org/2002%20Census%20Final%20Reportdoc.pdf.

———.2006b. National Statistics Databank, Agriculture and Fisheries. Area Planted and Production of Selected Food Crops, 1980–2004. http://www.ubos.org.

———. 2006c. Uganda National Household Survey 2005/2006. http://www.ubos.org/nada/

Uganda National Council for Science and Technology (UNCST). 2006. A Gap Analysis Study of Communication and Outreach Strategy for Biotechnology and Biosafety in Uganda. Unpublished Report.

Wedel, M., and W. Kamakura. 2000. *Market Segmentation: Conceptual and Methodological Foundations*. Boston: Kluwer Academic Publishers.

Wesseler, J. 2003. Resistance Economics of Transgenic Crops: A Real Option Approach. In Laxminarayan, R. (ed), *Battling Resistance to Antibiotics and Pesticides* pp. 214–37. Washington, D.C.: Resources for the Future Press.

———. 2009. The *Santaniello* Theorem of Irreversible Benefits. *AgBioForum,* 12(1): 8-13.

Wesseler, J., Scatasta, S., and E. Nillesen. 2007. The Maximum Incremental Social Tolerable Irreversible Costs (MISTICs) and Other Benefits and Costs of Introducing Transgenic Maize in the EU-15. *Pedobiologia* 51 (3): 261–69.

World Bank. 2008. *The World Development Report, Agriculture for Development*. Washington DC: World Bank. http://siteresources.worldbank.org/INTWDR2008/Resources/2795087-1192111580172/WDROver2008-ENG.pdf. Accessed on 5 October 2009.

Zhang, C., Bai, J., Huang, J.K., Hallman, W.K., Pray, C., and H.L. Aquino. 2004. Consumer Acceptance of Genetically Modified foods: A Comparison Between the US and China. Paper Presented at the American Agricultural Economics Association Annual Meeting, Held 1-4 August 2004 in Denver, Colorado, USA. http://purl.umn.edu/20026.

# Summary

Banana production in Uganda is limited by several productivity constraints such as pests, diseases, soil depletion, and poor agronomic practices. In the mid 1990s, Uganda launched its long-term approach of breeding for resistance to banana (*Musa* spp.) productivity constraints using genetic modification methods. The strategy for genetic modification is to develop genetically modified (GM) varieties that are resistant to local pests and diseases, have improved agronomic attributes, and are acceptable to consumers. It is expected that introducing a disease free GM banana variety would provide both immediate and future benefits through the positive effects on yield, product quality, production costs and/or other crop characteristics, which would improve the livelihood of the poor subsistence farmers. Currently, fungal resistant GM bananas are still undergoing biosafety field assessments. After a thorough environmental and food safety assessments GM bananas are expected to be released into the environment for commercialization.

However, while little is known about producer and consumer perceptions toward the technology in Uganda, the introduction of GM bananas is likely to generate a wide range of concerns, as it has in other African countries. The objective of this thesis is to illustrate the relevance of socioeconomic analyses for supporting biotechnology decision-making and in particular the importance of consumer perceptions, but also for contributing to the development and implementation of biosafety regulations.

In this study, I present a general approach using a GM banana as an example, while assuming that the GM banana has passed standard food and biosafety safety assessments and can be considered as being safe. The following issues are addressed: (i) the potential social incremental benefits and costs under effects of irreversibility, flexibility and uncertainty of introducing GM bananas in Uganda; (ii) the consumers' knowledge, attitudes and perceptions (KAP), and their implications for introducing GM bananas in Uganda in particular and other GM crops in general; (iii) the influence of preference heterogeneity on choice of banana bunch attributes among individual households, and between urban and rural households; (iv) the consumers' willingness to pay for the values accruing from GM bananas given a farm level benefit; and (v) the overall assessment of the effects of introducing GM bananas and its

implications on banana producers and consumers in Uganda. These issues are covered in chapters 2 through 6 of this thesis, and they hold numerous implications for scientists, policy makers (regulators), the public, and other stakeholders.

In chapter 2, a real option approach is followed in order to calculate the maximum incremental social tolerable irreversible costs (MISTICs) and the social incremental reversible benefits (SIRBs) of introducing a GM banana in Uganda. The MISTICs associated with the adoption of a GM banana in Uganda are calculated and presented for different risk-free and risk-adjusted rates of return. The results show the MISTICs to be between approximately US$176 million and US$359 million per year, or between US$282 and US$451 per hectare per year. Additionally, results indicate the average annual MISTICs per household are approximately US$ 38. This implies that only if the average household is willing to give up more than US$ 38 annually for not having GM bananas introduced should an immediate release be postponed. In the case where approval of the GM banana is delayed due to missing regulatory procedures and protocols, Uganda will forego potential benefits (SIRBs) in the approximate range of US$179 million to US$365 million per year. This foregone benefit can be an indicator of how much Uganda can pay to compensate for potential damages. Moreover, the SIRBs provide a clue about the maximum costs farmers would endure in order to comply with biosafety regulations, including the cost of implementing coexistence policies and after deducting planting costs per hectare. Based on the MISTICs results, it is evident that Uganda loses from not introducing a fungal resistant GM banana. Clearly, this chapter demonstrates a relationship between agricultural policy, R&D, technology delivery and impact, which shows an inverse relationship between stringency (precautionary approaches) and technology delivery. That is, the more stringent the approval process, the more potential benefits are foregone annually, which impacts both the scientists and the technology end users negatively. The chapter also provides new contributions to the economics of biotechnology literature in developing countries, in particular the biosafety debate.

In chapter 3, I investigate the underlying latent structure of the consumers' knowledge, attitudes and perceptions (KAP) toward GM banana in Uganda. The methodology used is an explanatory factor analysis. The analysis of KAPs results in three categories including benefit, food-environment risk, and health risk KAPs. The KAP toward GM crops among rural and urban consumers vary due to a number of socioeconomic characteristics, which suggests a rural-urban bias. Results show that if quality benefits are provided consumers are more willing to accept GM bananas, but at the same time they are concerned about the unknown negative effects of the technology. Moreover, results show that rural consumers value the quality benefits, while urban consumers are more concerned about the safety of the technology. Education and income have negative effects on GM banana acceptability. Results further indicate that there is a relatively high level of awareness and trust in local leaders and extension workers. Respondents were less aware of the Uganda National Council of Science and Technology (UNCST) and the Consumer Education Trust (CONSENT), the two main agencies responsible for informing consumers about GM food. This chapter thereby identifies the consumers' knowledge, attitudes, and perceptions and institutional awareness in relation to the introduction of a GM banana. It contributes to the ever-changing information about GM crops to which consumers are exposed.

In chapter 4, I investigate the heterogeneity in consumers' preferences for different banana attributes in Uganda. Using choice experiment data, I specifically analyze the preference heterogeneity resulting from locational and household level characteristics. This helped to test whether consumers in rural and urban locations value banana attributes differently. I use a random parameter logit model with interactions of respondent-specific household characteristics and choice-specific attributes in the utility function to investigate the preference heterogeneity, and to account for the source of unobserved heterogeneity. The results show that there is substantial conditional and unconditional heterogeneity. The impacts of specific household characteristics of the consumers on their valuation of the banana bunch attributes were significant, indicating the importance of considering such characteristics in explaining the sources of conditional heterogeneity. Results show that urban and rural preferences differ towards the introduction of a GM banana. The low-income rural households with larger household sizes value the GM technology that generates benefits to producers more highly than the urban ones. Further, results show that education negatively influences consumers' willingness to pay for GM bananas. Clearly, this chapter confirms that there are significant differences in preferences for banana bunch attributes between urban and rural households in Uganda. Increasing the importance of consumers, producers, and producers that happen to be consumers, participation in the decision-making process for approval and in marketing chains can help to reduce negative perceptions. This is important, not only because of the benefits, but also because of negative responses such as anti-GM banana campaigns this may trigger otherwise.

Unlike in chapter 4 where random parameter logit models with interactions and split samples were used to explain heterogeneity of preferences at individual level, in chapter 5 I employ a latent class model, which is a more recent model to investigate the sources of preference heterogeneity at segment level. This 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 from one segment to another. The number of segments is determined endogenously by the data. The fitting 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, perceptions and attitudes. Furthermore, respondent characteristics affect choices indirectly through their impact on segment membership. The findings show that there is significant heterogeneity in consumer preferences in our sample. The analysis identified two distinct segments of banana consumers in Uganda, the *potential GM banana consumers* and *potential GM banana opponents*. The former represents 58 percent of the sampled population and reside more in rural areas, while the latter represent 42 percent of the sample and are mostly found in urban areas. The *potential GM banana consumers* are mostly located in the rural areas of the Eastern Region, where banana pests and diseases are prevalent. These consumers are also 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 have relatively lower monthly incomes. They would be willing to pay larger premiums for GM bananas and to ensure producers of bananas derive higher benefits. These results are also consistent with results in chapters 3 and 4. In contrast, the *potential GM banana opponents* 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. Most of these consumers are older and better off; they reside mainly in urban areas of the Southwestern Region and Central Region, and mostly associate GM banana with risks (i.e., food, environment and health risks). Furthermore, the total WTP for the *potential GM banana consumers* and the total willingness to accept for the *potential GM banana opponents* are significant and large. Further analysis is required to investigate these welfare impacts and to determine whether or not the former (the majority of whom are rural consumers) can potentially compensate the latter (mostly urban consumers) if a GM banana is introduced in Uganda. This chapter confirms that GM banana could be a potentially pro-poor biotechnology, and its introduction would benefit the most rural households who grow and buy banana. It further supports other findings in the literature that better educated people are on average more strongly opposed towards GM banana and this not only in urban areas but also in rural. But findings indicate that stressing the potential benefits the technology may provide to farmers is more important among rural consumers than urban ones. Chapters 4 and 5 widen the application of the choice experiment by linking both the consumers and adopters of the GM banana, which is a new contribution. In addition, the inclusion of benefits for producers as an attribute in consumer preferences towards GM food often have not been considered in studies on consumer WTP. Finally, the chapters contribute to debate on how African elites view GM food. However, future research is required to understand in more detail why urban consumers as well as rural and urban elites derive disutility from the introduction of a GM banana and the associated benefits for producers.

In chapter 6, the empirical findings estimated in chapters 2, 4, and 5 are integrated in an economic welfare analysis to provide an overall assessment of the effects of introducing genetically modified bananas on banana producers and consumers. I compare the maximum incremental social tolerable irreversible costs (MISTICs) associated with the immediate introduction of a GM banana with the estimated total willingness to pay (WTP) values for the GM banana for different scenarios. I apply the concept of compensating surplus to consumers' preferences for a GM banana, and make simulations based on different combinations of impacts associated with GM banana introduction strategies to estimate the consumers' welfare measures. Welfare measures are estimated for the best-fit latent class model. The results show that there are respondents who gain and who lose from the introduction of a GM banana in the data, which is consistent with results in chapter 5. The *potential GM banana consumers* who are mostly located in rural areas show a much higher willingness to pay for all the proposed GM banana alternatives, particularly a GM banana which is characterized by large bunches and large benefits to producers, than their counterparts. With this finding, it is evident that benefits to producers played a significant role in the valuation of the banana bunch attributes. Nonetheless, when the *potential GM banana* *opponents'* households are considered further, their total WTP for the proposed banana improvement scenarios are negative and the absolute value above their estimated average MISTICs per bunch. With this finding I argue that, on the one hand, the *potential GM banana opponents* are likely to pay more than the threshold value of not having a GM banana introduced in Uganda. On the other hand, however, the calculated MISTICs per bunch for the *potential GM banana opponents'* households are generally low, which range approximately between US$ 0.15 and US$ 0.36. This finding implies that if the biosafety regulators are to address the concerns of the *potential GM banana opponents*, those additional costs may not exceed the potential benefit ranging between US$ 179 to 365 million per year. This chapter shows that for all scenarios welfare improves over the status quo, implying that the introduction of a GM banana would be beneficial for all Ugandans. Nevertheless, if such a GM banana is introduced its introduction may result in strong opposition from the opponent segment of the population, which is composed of mainly urban consumers. The implication is that the choice of the GM banana to benefit the whole society would depend on the cost of reducing opposition, which needs further investigation. This chapter contributes to literature of cost-benefit analysis by integrating the MISTICs with the consumers' WTP for a GM banana. The chapter explicitly analyses the impact of introducing the GM banana on banana producers and consumers based on the results of the two approaches.

Numerous policy implications can be drawn from this thesis as a whole. First, given the potential and significant economic benefits from the introduction of a GM banana, one might conclude that NARO has to work harder to push the GM banana through the biosafety protocols as promptly and efficiently as possible. Second, the government policies of delaying the introduction of GM bananas are more in line with the views of wealthier and better educated citizens than with the views of the majority of the population. But a careful approach towards introducing GM banana is needed to avoid strong urban consumer resistance. Third, if the GM banana is to be beneficial to all Ugandans, regulators would need to consider mechanisms of compensating those who may lose from its introduction. This can be done by providing more and reliable information about the safety of the technology, which could be channeled through (in addition to the current institutions) local authorities and extension workers. This strategy can help offsetting the negative knowledge, attitudes and perceptions toward GM technology, especially among urban consumers. Fourth, there is a need to broaden

the scope of biosafety processes now primarily focused on risk to include food security considerations and agricultural development. This calls for more funding for R&D. Finally, the decision to consider socioeconomic impacts for other GM crops elsewhere depends on the crop and the country. The research methodology in this thesis provides the basis for empirical studies for other crops.

# Samenvatting

Bananenproductie in Uganda is gelimiteerd door verschillende productiviteitsbeperkingen zoals plagen, ziektes, gronduitputting en slechte agronomische gebruiken. In de jaren negentig heeft Uganda zijn lange termijn plan bekend gemaakt om door middel van genetisch gemodificeerde methodes resistente bananen (*Musa* spp.) te telen tegen de verschillende productiviteitsbeperkingen. De strategie voor genetische modificatie is het ontwikkelen van genetisch gemodificeerde (GM) soorten die resistent zijn tegen lokale plagen en ziektes, die agronomische eigenschappen verbeteren en die acceptabel zijn voor consumenten. Het is verwacht dat de introductie van een ziektevrije GM banaansoort zowel voor directe als toekomstige baten zal zorgen, door middel van de positieve effecten op productie, productkwaliteit, productiekosten en/of andere karakteristieken van het gewas die de levensstandaard verbeteren van arme zelfonderhoudende boeren. Op dit moment ondergaan schimmelresistente GM bananen nog steeds veiligheidsbeoordelingen. Na een grondige milieu- en voedselveiligheidsbeoordeling wordt verwacht dat GM bananen op de markt worden gebracht.

Hoewel weinig bekend is over de percepties van producenten en consumenten ten opzichte van de GM technologie in Uganda, zal de introductie van GM bananen waarschijnlijk een brede reeks aan zorgen genereren, net als in andere Afrikaanse landen. Het doel van dit proefschrift is het illustreren van de relevantie van sociaal-economische analyses voor het ondersteunen van biotechnologische besluiten, met bijzonder aandacht voor de betekenis van de percepties van consumenten, en het bijdragen aan de ontwikkeling en implementatie van veiligheidsbepalingen.

In deze studie presenteer ik een algemene benadering met als voorbeeld GM bananen, met als aanname dat de GM bananen door de veiligheidsbeoordelingen zijn gekomen en als veilig kunnen worden beschouwd. De volgende kwesties zijn behandeld: (i) de potentiële maatschappelijke netto baten en kosten, welke onderhevig zijn aan effecten van onomkeerbaarheid, flexibiliteit en onzekerheid van het introduceren van GM bananen in Uganda; (ii) de kennis, houdingen en percepties (KAP) van consumenten en de implicaties hiervan voor het introduceren van GM bananen, en andere GM gewassen, in Uganda; (iii) de invloed van heterogene voorkeuren voor eigenschappen van de bananentros onder individuele huishoudens, en tussen stedelijke en landelijke huishoudens; (iv) de bereidheid van consumenten om te betalen voor de waarden die voortkomen uit de productie van GM bananen, gegeven een baat op bedrijfsniveau; en (v) de algehele beoordeling van de effecten van het introduceren van GM bananen en de implicaties hiervan op bananenproducenten en consumenten in Uganda. Deze kwesties worden behandeld in hoofdstukken 2 tot en met 6 van dit proefschrift, en ze bevatten meerdere implicaties voor wetenschappers, beleidsmakers, het publiek en andere belanghebbenden.

In hoofdstuk 2 is een reële optie benadering gevolgd om de maximale netto maatschappelijk getolereerde onomkeerbare kosten (MISTICs) en de maatschappelijke netto omkeerbare baten (SIRBs) te berekenen van het introduceren van een GM banaansoort in Uganda. De MISTICs die geassocieerd zijn met de introductie van een GM banaansoort in Uganda zijn berekend en gepresenteerd voor verschillende interest- en discontopercentages. De resultaten laten zien dat de MISTICs ongeveer tussen US$176 miljoen en US$359 miljoen per jaar liggen. Daarnaast geven de resultaten aan dat de gemiddelde jaarlijkse MISTICs per huishouden ongeveer US$38 zijn. Dit wil zeggen dat, alleen als het gemiddelde huishouden bereid is om meer op te geven dan US$38 per jaar voor het niet hebben geïntroduceerd van GM bananen, een directe introductie zou zijn uitgesteld. In het geval waar de goedkeuring van de GM banaansoort is uitgesteld vanwege ontbrekende beleidsprocedures en protocollen, zal Uganda potentiële baten (SIRBs) voorzien die tussen ongeveer US$179 miljoen en US$365 miljoen per jaar liggen. Deze voorziene baten kunnen een indicator zijn van hoeveel Uganda kan betalen om te compenseren voor potentiële schade. Verder geven de SIRBs een indicatie van de maximale kosten die boeren zouden dragen om te voldoen aan de veiligheidsbepalingen, inhoudende de kosten van het implementeren van co-existentiebeleid en kosten voor het planten van de GM bananen per hectare. Gebaseerd op de MISTICs resultaten is het duidelijk dat Uganda verliest door het niet introduceren van een schimmelresistente GM banaansoort. Het is duidelijk dat dit hoofdstuk een relatie weergeeft tussen agrarisch beleid, R&D, technologische levering en effect, wat een omgekeerde relatie laat zien tussen voorzorgsbenaderingen en technologische levering. Dat wil zeggen, hoe voorzichtiger het goedkeuringsproces, hoe groter de jaarlijks potentiële misgelopen baten zijn, wat een negatieve invloed heeft zowel op wetenschappers als op de eindgebruikers van de technologie. Dit hoofdstuk draagt ook bij aan de economische en biotechnologische literatuur in ontwikkelingslanden, voornamelijk aan het debat over veiligheid.

In hoofdstuk 3 onderzoek ik de onderliggende onobserveerbare structuur van consumentenkennis, houdingen en percepties (KAP) tegenover GM bananen in Uganda. De methodologie die is toegepast is een verklarende factor analyse. De analyse van KAP resulteert in drie categorieën, namelijk (i) baten, (ii) voedsel-milieu risico en (iii) gezondheidsrisico KAPs. De KAP ten opzichte van GM gewassen onder consumenten van landelijke en stedelijke gebieden variëren vanwege een aantal sociaal-economische karakteristieken, welke een landelijk-stedelijk vooroordeel suggereren. Resultaten laten zien dat als er baten aan kwaliteit zijn verbonden, dan zijn consumenten meer bereid GM bananen te accepteren, maar tegelijkertijd zijn ze bezorgd over de onbekende negatieve effecten van de GM technologie. Bovendien laten de resultaten zien dat landelijke consumenten de baten van kwaliteit waarderen, terwijl stedelijke consumenten meer bezorgd zijn over de veiligheid van de technologie. Opleiding en inkomen hebben negatieve effecten op aanvaardbaarheid van GM bananen. Verder wordt er aangetoond dat er een relatief hoog niveau van bewustzijn van en vertrouwen is in lokale ambtenaren en in ambtenaren die werkzaam zijn in de agrarische sector. Ondervraagden waren zich minder bewust van Uganda's Nationale Raad van Wetenschap en Technologie (UNCST) en van de Consumer Education Trust (CONSENT), welke de twee belangrijkste instellingen zijn die verantwoordelijk zijn voor het informeren van consumenten over GM voedsel. Dit hoofdstuk identificeert daarbij kennis, houdingen en percepties van consumenten en het institutionele bewustzijn in relatie tot de introductie van GM bananen. Het draagt bij aan de altijd veranderende informatie over GM gewassen waar consumenten aan blootgesteld zijn.

In hoofdstuk 4 onderzoek ik de heterogene voorkeuren van consumenten voor verschillende eigenschappen van bananen in Uganda. Door het gebruik van keuze-experimentele data analyseer ik in het bijzonder de heterogene voorkeuren die het resultaat zijn van karakteristieken van de lokale bevolking en van huishoudens. Dit heeft geholpen om te kunnen testen of consumenten in stedelijke en in landelijke gebieden eigenschappen van bananen verschillend waarderen. Ik gebruik een random parameter logit model, met in de nutsfunctie de interacties tussen karakteristieken van ondervraagde huishoudens en specifieke keuze eigenschappen, om de heterogene voorkeuren te onderzoeken en om rekening te houden met de bron van niet waargenomen heterogeniteit. De resultaten laten zien dat er voorwaardelijke en onvoorwaardelijke heterogeniteit is. De effecten van specifieke karakteristieken van huishoudens op de waardering van de eigenschappen van de bananentros waren significant, wat wijst op het belang van het overwegen van zulke karakteristieken bij het verklaren van bronnen van voorwaardelijke heterogeniteit. Resultaten laten zien dat stedelijke en landelijke voorkeuren verschillen wat betreft de introductie van GM bananen. Landelijke huishoudens met een laag inkomen en met een groter huishouden waarderen de GM technologie, die baten genereert voor producenten, meer dan stedelijke huishoudens. Resultaten laten verder zien dat onderwijs een negatief effect heeft op de bereidheid van consumenten te betalen voor GM bananen. Dit hoofdstuk bevestigt dat er significante verschillen zijn, in voorkeuren voor eigenschappen van een tros bananen, tussen stedelijke en landelijke huishoudens in Uganda. Negatieve percepties kunnen worden verminderd door het belang te laten toenemen van participatie van consumenten en producenten in het besluitvormingsproces tot goedkeuring en in de marketing. Dit is niet alleen belangrijk vanwege de baten, maar ook omdat het de negatieve reacties, zoals campagnes tegen GM bananen, kan reduceren.

In tegenstelling tot hoofdstuk 4, waar random parameter logit modellen zijn gebruikt met interacties en steekproeven om heterogeniteit van voorkeuren te verklaren op individueel niveau, gebruik ik in hoofdstuk 5 een latent class model, wat een meer recent model is om bronnen van heterogene voorkeuren te onderzoeken op segmentniveau. Deze benadering weerspiegelt een bevolking bestaande uit een eindig en identificeerbaar aantal segmenten, of groepen van individuele mensen. Voorkeuren zijn relatief homogeen binnen segmenten, maar verschillen wezenlijk tussen segmenten. Het aantal segmenten is endogeen bepaald door de data. Het passen van een individu in een specifiek segment is probabilistisch en hangt niet alleen af van sociale, demografische en economische karakteristieken van ondervraagden, maar ook van hun kennis, houdingen en percepties. Verder worden keuzes indirect beïnvloed door karakteristieken van ondervraagden, door middel van hun effect op het deel uitmaken van een segment. De bevindingen laten zien dat er in onze steekproef een significante heterogeniteit is in consumentenvoorkeuren. De analyse identificeert twee verschillende segmenten van consumenten van consumenten in Uganda, namelijk de *potentiële* *consumenten van GM bananen* en de *potentiële tegenstanders van GM bananen*. De consumenten van het eerste segment vertegenwoordigen 58 procent van de geteste bevolking en zijn voornamelijk woonachtig in landelijke gebieden. De consumenten van het tweede segment vertegenwoordigen 42 procent van de steekproef en wonen in stedelijke gebieden. De *potentiële consumenten van GM bananen* zijn meestal gevestigd in landelijke gebieden van de oostelijke regio, waar banaanplagen en ziektes heersen. Deze consumenten zijn ook jonger en hebben positieve meningen wat betreft de baten van GM voedsel en gewassen. Zij hebben grotere families, zijn minder vaak werkzaam buiten de boerderij en hebben relatief lagere maandelijkse inkomens. Zij zouden bereid zijn hogere premies te betalen voor GM bananen en voor het verzekeren van hogere baten voor banaanproducenten. Deze resultaten zijn ook consistent met resultaten in hoofdstukken 3 en 4. De *potentiële tegenstanders van GM bananen*, daarentegen, leiden significant negatief nut af van GM variëteiten en de geassocieerde baten. Leden van dit segment zijn echter bereid een korting te accepteren voor zowel GM banaansoorten als voor de bijbehorende baten voor producenten. De meeste van deze consumenten zijn ouder en rijker; ze wonen voornamelijk in stedelijke gebieden van de zuidwestelijke en centrale regio's, en ze associëren GM bananen meestal met risico's (i.e. voedsel, milieu en gezondheidsrisico's). Verder is de totale bereidheid om te betalen van *potentiële consumenten van GM bananen*, en de totale bereidheid om te accepteren van *potentiële tegenstanders van GM bananen*, significant en groot. Verdere analyse is nodig om deze welzijnseffecten te onderzoeken en om te bepalen of het eerste segment (waarvan de meerderheid in landelijke gebieden woont) potentieel kan compenseren voor het tweede segment (voornamelijk stedelijke consumenten) als een GM banaansoort wordt geïntroduceerd in Uganda. Dit hoofdstuk bevestigt dat de GM banaan een potentiële pro-arme biotechnologie is, en dat de introductie ervan de meest landelijke huishoudens, die bananen telen en kopen, zou baten. Verder ondersteunt het andere bevindingen in de literatuur dat beter opgeleide mensen, zowel in stedelijke als in landelijke gebieden, zich gemiddeld sterker verzetten tegen GM bananen. Bevindingen laten zien dat het benadrukken van potentiële baten van de technologie voor boeren belangrijker is onder landelijke consumenten dan onder stedelijke consumenten. Hoofdstukken 4 en 5 breiden de toepassing van het keuze experiment uit door consumenten en producenten van GM bananen te linken, wat een nieuwe bijdrage aan de literatuur is. Daarnaast is het opnemen van baten voor producenten als een eigenschap in consumentenvoorkeuren naar GM voedsel vaak niet beschouwd in studies naar bereidheid van consumenten om te betalen. Tot slot dragen de hoofdstukken bij aan het debat over de mening van de Afrikaanse elite over GM voedsel. Echter, verder onderzoek is vereist om in meer detail te begrijpen waarom zowel stedelijke en landelijke consumenten als de stedelijke elite negatief nut hebben van het introduceren van GM bananen en van de daartoe behorende baten voor producenten.

In hoofdstuk 6 zijn de empirische bevindingen uit hoofdstukken 2, 4 en 5 geïntegreerd in een economische welzijnsanalyse, om zo een algehele beoordeling te geven van de effecten van het introduceren van GM bananen op banaanproducenten en consumenten. Ik vergelijk de maximale netto maatschappelijk getolereerde onomkeerbare kosten (MISTICs), die geassocieerd zijn met de onmiddellijke introductie van een GM banaansoort, met de geraamde waarden van de totale bereidheid te betalen (WTP) voor de GM banaansoort, onder verschillende scenario's. Ik pas het concept van compensating surplus toe op consumentenvoorkeuren voor de GM banaan, en ik maak simulaties gebaseerd op verschillende combinaties van effecten die geassocieerd zijn met strategieën voor het introduceren van de GM bananen, om vervolgens effecten van het welzijn van consumenten te ramen. Welzijnseffecten zijn geraamd voor het best passende latent class model. De resultaten laten zien dat er ondervraagden zijn die profiteren en verliezen van de introductie van een GM banaansoort. Dit is consistent met de resultaten in hoofdstuk 5. De *potentiële consumenten van GM bananen* die voornamelijk gevestigd zijn in landelijke gebieden laten zien veel meer bereid te zijn dan hun tegenhangers om te betalen voor alle voorgestelde alternatieven van GM bananen, in het bijzonder de GM bananen die gekenmerkt zijn door grote trossen en grote baten voor producenten. Met deze bevinding is het duidelijk dat baten voor producenten een significante rol hebben gespeeld in de waardering van eigenschappen van de bananentros. Niettemin, wanneer de huishoudens van *potentiële tegenstanders van GM bananen* verder worden beschouwd, dan is hun totale bereidheid te betalen voor de voorgestelde scenario's, voor het verbeteren van bananen, negatief en ligt de absolute waarde daarvan boven de geraamde gemiddelde MISTICs per tros. Met deze bevinding redeneer ik, aan de ene kant, dat de *potentiële tegenstanders van GM bananen* waarschijnlijk bereid zijn meer te betalen dan de drempelwaarde van het niet hebben geïntroduceerd van de GM bananen in Uganda. Aan de andere kant zijn de berekende MISTICs per tros voor de huishoudens van *potentiële tegenstanders van GM bananen* over het algemeen laag, en deze liggen tussen ongeveer US$0.15 en US$0.36. Deze bevinding wil zeggen dat als de veiligheidsbeleidsmakers zich moeten richten op de zorgen van de *potentiële tegenstanders van GM bananen*, dan mogen deze extra kosten de potentiële baten niet overschrijden, welke tussen US$179 en US$365 miljoen per jaar zijn. Dit hoofdstuk laat zien dat onder alle scenario's het welzijn verbetert ten opzichte van de status quo, dat wil zeggen dat de introductie van GM bananen voordelig zou zijn voor alle Ugandezen. Niettemin, als GM bananen worden geïntroduceerd kan deze introductie leiden tot sterk verzet van het segment van de tegenstanders, welk voornamelijk bestaat uit stedelijke consumenten. De implicatie is dat de keuze om de hele maatschappij te laten profiteren van de introductie van de GM bananen afhangt van de kosten voor het reduceren van het verzet; dit vereist verder onderzoek. Dit hoofdstuk draagt bij aan de literatuur van kosten en baten analyses door de MISTICs te integreren met de bereidheid te betalen voor een GM banaansoort. Gebaseerd op de resultaten van de twee benaderingen, analyseert het hoofdstuk nadrukkelijk het effect van de introductie van de GM bananen op producenten en consumenten van bananen.

Talrijke beleidsimplicaties kunnen worden afgeleid uit dit proefschrift. Ten eerste, gegeven de potentiële en significante economische baten van de introductie van een GM banaansoort, kan men concluderen dat de National Agricultural Research Organisation (NARO) harder moet werken om de GM bananen zo spoedig en zo efficiënt mogelijk door het veiligheidsprotocol te laten komen. Ten tweede, overheidsbeleid voor het vertragen van de introductie van GM bananen ligt meer in lijn met de meningen van rijkere en beter opgeleide burgers dan met de meningen van de meerderheid van de bevolking. Maar een voorzichtige benadering voor het introduceren van GM bananen is nodig om sterk verzet van stedelijke consumenten te voorkomen. Ten derde, als alle Ugandezen profiteren van de GM bananen, dan zouden beleidsmakers mechanismes moeten overwegen ter compensatie voor diegenen die verliezen van de introductie. Dit kan worden gedaan door te voorzien in meer en betrouwbare informatie over de veiligheid van de technologie, wat verzorgd zou kunnen worden door lokale autoriteiten en ambtenaren die werkzaam zijn in de agrarische sector. Deze strategie kan helpen bij het compenseren van de negatieve kennis, houdingen en percepties ten aanzien van GM technologie, voornamelijk onder stedelijke consumenten. Ten vierde, er is een behoefte om het bereik van de veiligheidsprocessen, welke nu gericht zijn op risico, te verbreden met voedselveiligheidsoverwegingen en agrarische ontwikkelingen. Dit vereist meer financiering voor R&D. Tot slot, het besluit om sociaal-economische effecten te overwegen voor ander GM gewassen elders hangt af van het gewas en van het land. De onderzoeksmethodologie in dit proefschrift kan een basis zijn voor empirisch onderzoek naar andere gewassen.

# About the Author

Enoch Kikulwe was born on January 1st, 1970. He earned a BSc. in Agriculture (1995) and an MSc. in Agricultural Economics (2000) both from Makerere University, Kampala, Uganda. From 2000 to 2005, in Uganda, he worked as a research assistant at the National Agricultural Research Organization. He worked on several national and collaborative research projects, which involved survey design, data collection, and data analysis. In November 2005 he obtained a scholarship through the International Food Policy Research Institute (IFPRI), Washington, DC, USA, and started his PhD research at the Environmental Economics and Natural Resource Group (ENR) of Wageningen University, The Netherlands. During this research he followed his PhD education program and completed the course work at the Mansholt Graduate School of Social Sciences (MG3S), and visited IFPRI for collaborative work. Results of his PhD research have been presented at several international conferences, and published as discussion papers, book chapters, and journal articles. During his PhD position he also worked as a researcher at Wageningen University, and after submission he worked as an international consultant for the Food and Agriculture Organization of The United Nations.

# Training and Supervision Plan

**Annex to statement**
**Name Enoch Mutebi Kikulwe**
**PhD student, Mansholt Graduate School of Social Sciences (MG3S)**
**Completed Training and Supervision Plan**

| Description | Institute / Department | Year | ECTS* |
|---|---|---|---|
| **Courses:** | | | |
| MG3S Introductory Course 2006/I | Mansholt Graduate School of Social Sciences (MG3S) | 2006 | 1.5 |
| Techniques of writing and presenting a scientific paper | Wageningen Graduate Schools (WGS) | 2006 | 1.2 |
| Time planning and project management | WGS | 2006 | 1.5 |
| Getting your message across: Media Skills for scientific researchers | WGS | 2006 | |
| Proposal Writing | MG3S | 2006 | 6 |
| Microeconomics | Maastricht University | 2006 | 6 |
| Advanced Econometrics | Wageningen University | 2006 | 6 |
| Economic Models | Wageningen University | 2006 | 6 |
| Introduction to Environmental Economics Modelling | SENSE | 2006 | 5 |
| Economics and Management of Natural Resources | Wageningen University | 2006 | 6 |
| Discrete Choice Modelling | MG3S | 2007 | 1.5 |
| Irreversibilities, Uncertainties and Real Option Values | MG3S | 2008 | 4 |
| **Presentations at conferences and workshops:** | | | |
| Mansholt PhD Presentation, MG3S, Wageningen, Netherlands | | 2008 | 1 |
| International Consortium on Agricultural Biotechnology Research (ICABR), Ravello, Italy | | 2006 | 1 |
| International Consortium on Agricultural Biotechnology Research (ICABR), Ravello, Italy | | 2008 | 1 |
| Banana 2008, the International Banana Conference, Mombasa, Kenya | | 2008 | |
| Africa Biotechnology Congress, Nairobi, Kenya | | 2008 | |
| Africa Biotech Conference 2009, Entebbe, Uganda | | 2009 | |
| International Consortium on Agricultural Biotechnology Research (ICABR), Ravello, Italy | | 2009 | |
| IAAE 2009, the 27th International Conference of Agricultural Economists, Beijing, China. | | 2009 | |
| **Total (minimum 30 ECTS)** | | | **47.7** |

*One ECTS on average is equivalent to 28 hours of course work

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