The Economic Impact of Peanut Research on the Poor: The Case of Resistance Strategies to Control Peanut Viruses in Uganda

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(Abstract)

Economic impacts of research that developed Rosette virus-resistant peanut in Uganda are estimated, including the impacts on poverty. The impacts of technology on the cost of production at the household level are determined. This information is used to compute aggregate benefits in an economic surplus model. A probit model is used to identify the determinants of adoption using household data. Information regarding the determinants of adoption is combined with impacts of technology on the cost of production to identify income changes for adopting households. Foster-Greer-Thorbecke poverty measures are used to project changes in poverty for households that adopt. It is estimated that the poverty rate will decline by 1.3 percent as a result of the research.

To my parents

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Chapter 1: Introduction

Problem statement

There has been intense debate among economists about the nature and level of impacts of agricultural research on the poor. This debate comes at a time when public agricultural research funds have become tighter (Alston et al, 1998). Since 1985, total support to international agricultural research from USAID has decreased by 66 percent; support to national agricultural research systems has decreased by 71 percent and USAID technical agricultural staff numbers have decreased by 66 percent. These declines come as research systems face increasing challenges in responding to economic restructuring and environmental limitations (Alex, 1996). In meeting these new challenges, funding alone is not enough. Reversing the decline in funding for research programs is needed, but research institutions must redesign their programs and approaches to better respond to client needs and market-driven opportunities. Programs must become more results oriented and able to link activities with impacts, including impacts on the poor (Alex, 1996).

In most of Sub Saharan Africa, rural households depend largely on agriculture to earn a living. Agriculture as a share of GDP is 49 percent in Uganda, while 57 percent of rural Ugandans live below national poverty lines (IFAD, 2002). For people in many developing countries, peanuts are the principal source of digestible protein, cooking oil, and vitamins like thiamine, riboflavin and niacin (Savage and Keenan, 1994). In many Sub-Saharan African countries, women predominantly grow and manage the crop. Therefore peanut cropping has a direct bearing on the economic and nutritional well being of household members. The crop has significant advantages that make it well suited for poor farmers. Peanuts, because they are legumes, improve soil fertility due to their capacity to fix nitrogen, and therefore make the soil more productive for cereal crops in subsequent seasons. The crop also requires low inputs, i.e., it can be grown under rain-fed conditions without chemical fertilizer, making it suitable for cultivation in low input agriculture by smallholder farmers.

Peanut production in Sub Saharan Africa is retarded by the prevalence of viruses and diseases affecting the crop (Gibbons, 1977). The most prevalent is the Groundnut Rosette disease, a viral infection that was first reported in Tanganyika (now Tanzania) in 1907 (Naidu, et al, 1999). According to Naidu et al (1999) there had been Groundnut Rosette disease epidemics in Sub Saharan Africa in the years after its first discovery, but the long-term consequences of such epidemics on smallholder farmers remain unknown probably due to misdiagnosis resulting from a lack of adequate resources to identify and document the causative agent. The International Crop Research Institute for Semi-Arid Tropics (ICRISAT) reports that Groundnut Rosette disease has been and continues to be responsible for devastating losses to peanut production in Africa. For example, the rosette epidemic in 1994-1995 in central Malawi and eastern Zambia destroyed the crop to such an extent that the total area of groundnut grown in Malawi fell from 92,000 ha in 1994-1995 to 65,000 ha in 1995-1996. Losses in Zambia were estimated at US$ 5 million that year. Overall value of the yield loss due to rosette disease in Africa is estimated at about US$ 156 million per annum. The potential yield gain due to management of the disease is estimated at about US$ 121 million.

Yield losses due to groundnut rosette disease depend on the growth stage of the plant when infection occurs. If infection occurs before flowering, 100 percent yield losses are possible, while losses are variable if infection occurs between flowering and the pod maturing stage. Subsequent infections cause negligible effects (Naidu et al, 1999).

Agricultural research can benefit the poor in a number of ways. Benefits may result from controlled disease spread, higher yields, reduced risk, lower production costs, lower food prices, and increased marketed surplus with possible positive effects on household income. Regions that adopt new technologies tend to have greater employment opportunities for landless laborers and may have higher wages than non-adopting regions, but employment also depends on the technology. Input and output linkages can benefit the local non-farm economy of the adopting region, thus benefiting the poor through increased migration opportunities and reduced food prices for all. Any technology that results in increased crop productivity of poor farmers, in this case by restricting the prevalence of peanut viruses, could potentially affect their welfare.

Among the peanut CRSP research thrusts, little effort has been devoted to estimating the effects of new technologies on crop productivity or on incomes and poverty of rural farmers and consumers. Economic impacts of research on peanut viruses and disease resistance in Uganda are therefore unknown. An example of such research is the project on "Control strategies for peanut viruses: Transgenic resistance, natural resistance, and virus variability"[1] being carried out in Uganda and Malawi, and whose benefits have never been extensively examined. An understanding of the impact of this research, at least in Uganda, could relay better information pertaining to the level of

[1] The title of the Peanut CRSP project is, Control Strategies for Peanut Viruses: Transgenic Resistance, Natural Resistance, and Virus Variability; project number UGA28P. The Principal Investigator is Prof. Michael Deom of University of Georgia in collaboration with scientists in Malawi, Uganda.

effort and possibly amount of funding that is required if similar projects, either in the present or future, are to be implemented successfully.

Knowledge of the extent of impact on poverty could provide information that could lead to a reallocation of scarce resources to activities with the greatest probabilities of reaching intended objectives. This could lead to better decisions being made and possibly minimize resource waste. In addition, continued research support may depend on demonstrating effects on intended beneficiaries.

Objectives of the study

Broad objectives

1) To estimate the economic impact of the peanut virus research in Uganda;
2) To estimate the impact of Peanut CRSP virus research on the poor in Uganda.

Specific objectives

1) To understand the rosette resistant peanut adoption profile for Eastern Uganda;
2) To understand the determinants of adoption;
3) To determine the distribution of income gains among adopting households; and
4) To estimate changes in poverty of adopting households.

Methods

To realize the objectives of this study, extensive data were collected and analyzed. It is important to identify from the outset for example the location and socio economic profiles of farmers concerned. Therefore, national household surveys, conducted by Uganda Bureau of Statistics in collaboration with the World Bank and International Food Policy Research Institute (IFPRI) provided the source of this household information in this study.

Economic surplus estimation is the first major step of the study. This is carried out using interview data on adoption profiles and research costs collected during a visit to a research institute in Uganda and interacting with breeders, extensions officers, farmers, and other industry experts.

Household production, consumption and expenditure data are then used to compute poverty indices using the Foster-Greer-Thorbecke additive measures of poverty, which permit poverty decomposition by group. Realized research benefits from the economic surplus model are then incorporated into calculation of the poverty indices and used to estimate how households of differing economic profiles move relative to the poverty line as their incomes are impacted upon by the research benefits.

Organization of thesis

A detailed literature review is presented in Chapter 2, with a significant portion devoted to the description of the peanut industries in Uganda. The theoretical framework is presented in chapter 3, results are presented in chapter 4, and conclusions and recommendations are presented in chapter 5.

Chapter 2: Literature Review

Introduction

This chapter briefly summarizes the peanut industry, first globally and then in Uganda. The objective is to highlight key issues in peanut production and trade and how they affect peanut producers in Uganda.

The global peanut industry

Production

According to United States Department of Agriculture (USDA) forecasts for crop year 2003/2004 (FAS, 2003), of the world oilseeds total production of 333 million metric tons, peanut represents about 10 percent compared to 60 percent for soybean, 10 percent for cotton seed and 8 percent for both rape and sunflower seed. Furthermore, USDA data indicate that on average for the 1972-2000 period, developing countries accounted for 90 percent of world production. The world average in-shell peanut production averaged 29,108 thousand metric tons between 1996 and 2000, and grew at an annual rate of 2.5 percent from 1972 to 2000. This production growth was due to both an increase in harvested area and in peanut yields, although the later played a more fundamental role (Revoredo and Fletcher, 2002).

Table 2.1: Annual average world peanut production, 1972 – 2000 (‘000 metric tons)

Region	**1972-75**	**1976-80**	**1981-85**	**1986-90**	**1991-95**	**1996-00**	**% change**
Africa							
E. Africa	998	1,003	620	567	569	595	-40.42
S. Africa	799	690	370	395	365	592	-25.88
W. Africa	2,776	2,579	2,538	2,750	3,085	4,236	52.63
Subtotal	4,573	4,273	3,528	3,711	4,019	5,423	18.60
America							
N. America	1,664	1,665	1,807	1,809	1,944	1,786	7.31
S. America	867	842	577	504	446	621	-28.35
Subtotal	2,531	2,507	2,384	2,313	2,390	2,407	-4.91
Asia							
E. Asia	2,399	2,703	4,794	6,017	8,244	11,581	382.69
S.E. Asia	1,295	1,448	1,730	1,781	1,914	2,144	65.62
S.W. Asia	5,528	5,724	6,305	7,344	7,964	7,239	30.95
Subtotal	9,222	9,875	12,828	15,142	18,123	20,964	127.33
Rest of the World	123	155	166	193	255	314	156.13
World total	16,448	16,809	18,906	21,360	24,787	29,108	76.97

Source: Extracted from Revoredo and Fletcher (2002)

Although aggregate world production of peanuts has increased over the last thirty years, there has been significant regional variation. Most of the growth in output has occurred in Asia, and more specifically in East Asia (table 2.1). The African continent, on average, experienced a 19 percent growth in output, although regional disparities are apparent.

Table 2.2: Five year average peanut yield by region, 1972 – 2000 (metric tons per ha)

Region	1972-75	1976-80	1981-85	1986-90	1991-95	1996-00	% change
Africa							
E. Africa	0.92	0.86	0.65	0.72	0.71	0.69	-25.20
S. Africa	0.70	0.69	0.48	0.58	0.57	0.69	-2.18
W. Africa	0.69	0.69	0.74	0.75	0.74	0.90	30.55
Subtotal	0.73	0.72	0.68	0.72	0.72	0.85	15.22
America							
N. America	2.60	2.59	2.91	2.45	2.54	2.71	4.27
S. America	1.17	1.14	1.70	1.73	1.76	1.58	35.11
Subtotal	1.83	2.02	2.48	2.25	2.34	2.28	24.93
Asia							
E. Asia	1.22	1.32	1.80	1.94	2.41	2.84	131.66
S.E. Asia	0.94	1.08	1.18	1.15	1.22	1.37	46.35
S.W. Asia	0.78	0.80	0.86	0.92	0.96	0.91	17.26
Subtotal	0.88	0.94	1.12	1.20	1.36	1.54	74.88
Rest of the World	1.62	1.60	1.66	1.96	2.28	2.41	49.02
World total	0.91	0.95	1.07	1.13	1.24	1.37	51.56

Source: Extracted from Revoredo and Fletcher (2002)

West Africa accounted for most of the growth (53 percent), while Southern and East Africa experienced massive production declines (-40 percent and -26 percent respectively). Africa’s share of total world production has decreased, affected by the decline of the peanut oil and meal markets. Utilization of peanuts declined in both the Eastern and Southern Africa regions, while West Africa almost doubled its utilization over the last 30 years. The decrease in utilization in East and Southern Africa was due to contraction in both the food and crushing industries, in the same regions. In West Africa, the increase in utilization was due to a substantive and steady increase in the use of peanuts for food purposes.

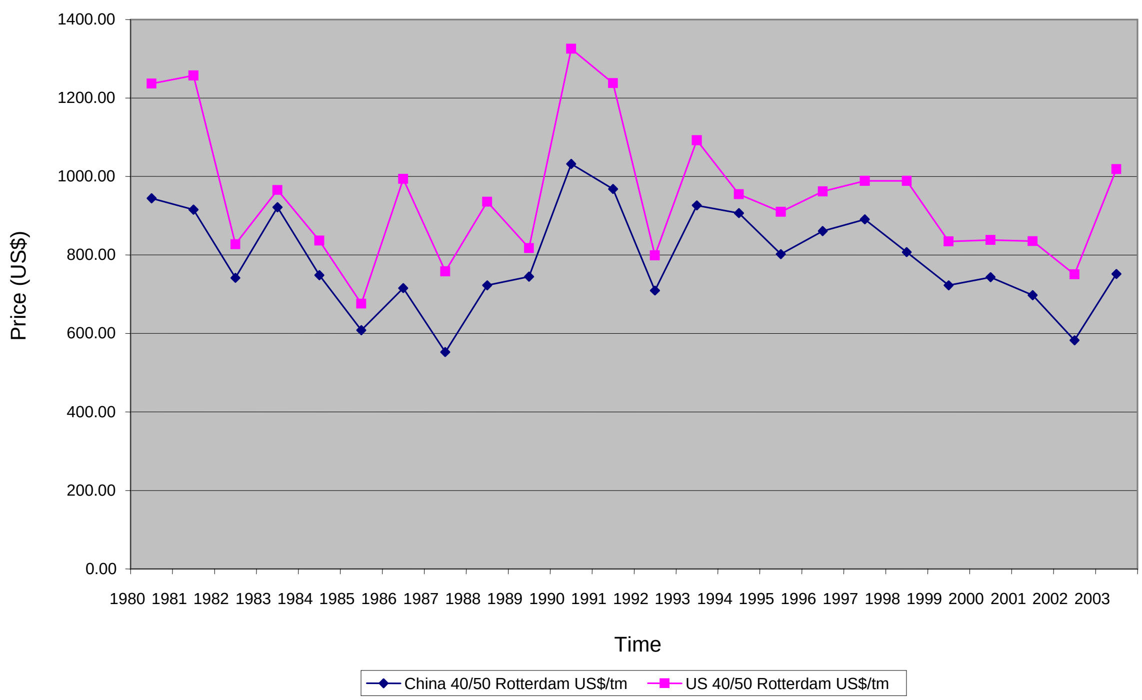
Yield by region has grown steadily, with the world average yield moving up from 0.91 metric tons per hectare in 1972-75 to about 1.37 presently. Peanut yields in Eastern and Southern Africa decreased from 1972 to 2000 by 25 percent and 2 percent respectively. These decreases in yield have been attributed to the prevalence of drought, which creates a favorable environment under which some disease causing agents like rosette can thrive. Yields have in general remained steady in North America, but increased significantly in the rest of the Americas. Asia recorded record yield increases, contributing to the increased production output (table 2.1) with most of the yield increases in the East Asian subcontinent.

Trade

The world market for peanuts may be considered a residual market, in the sense that only a small proportion of world production is traded internationally, and most of the production is domestically utilized (Revoredo and Fletcher, 2002). The average share of world peanut production exported since the 1970's has been constant at about 5 percent, although the total volume of exports has been steadily rising since the late 1980s, increasing from about 1.1 million metric tons per year then, to about 1.5 million metric tons during the 1996 to 2000 period (Revoredo and Fletcher, 2002).

World peanut supply has traditionally been dominated by three countries, the USA, China and Argentina (FAS, 2003) with these three comprising about 60 percent of total world trade. In the early 1970s, African countries were among the major suppliers to the world market, but as peanut trade shifted from oil to a market for peanut for food purposes, their presence in export markets declined in relative and absolute terms (Revoredo and Fletcher, 2002). The export position of African countries was worsened by the presence of aflatoxin in their production, causing a shift to competing oil sources like soybean (Carley and Fletcher, 1995). International prices for peanuts have been relatively stable, although they were characterized by two major surges that occurred in 1980 to 1983 and again between 1989 and 1992. Figure 2.1 presents the evolution since 1980 of annual real average prices for shelled peanuts, 40/50 standard edible grade prices in Rotterdam, the world reference point.

Figure 2.1: International real prices 40/50s for shelled peanuts, standard edible grade



There is a gap between the price of the US and Chinese crops (figure 2.1), with the US crop paid more on average by about $150 on a per metric ton basis. This spread in favor of the US is associated with factors such as quality and export reliability (Revoredo and Fletcher, 2002).

Uganda in brief

Uganda is an East African country to the west of Kenya with a total land area of 236,040 sq km (slightly smaller than Oregon). It has a tropical climate, generally rainy with two dry seasons (December to February and June to August) although semiarid to the northeast. Uganda is one of the poorest countries in the world. Per capita income in 2003 was estimated to be at about $259. Life expectancy at birth dropped from 47 years in 1990 to only 43 years in 2001. The percentage of the population with improved access to water remains relatively low at about 52 percent in 2000 (45 percent in 1990). Over the last couple of years Uganda has made substantial progress in terms of human development. Infant Mortality dropped from 100 per 1,000 in 1990 to 79 per 1,000 in 2001, gross enrollment rates for primary schooling increased from 71 percent in 1990 to 136 percent (meaning that more students are going to school than expected, partly due to repeat students, and attendees who are not necessarily of ‘school going age’) in 2001 although girls enrollment, is considerable lower. Total adult literacy rose from 56 percent in 1990 to 67 percent in 2001, while youth literacy increased from 70 percent in 1990 to 79 percent in 2001 (World Bank, 2003).

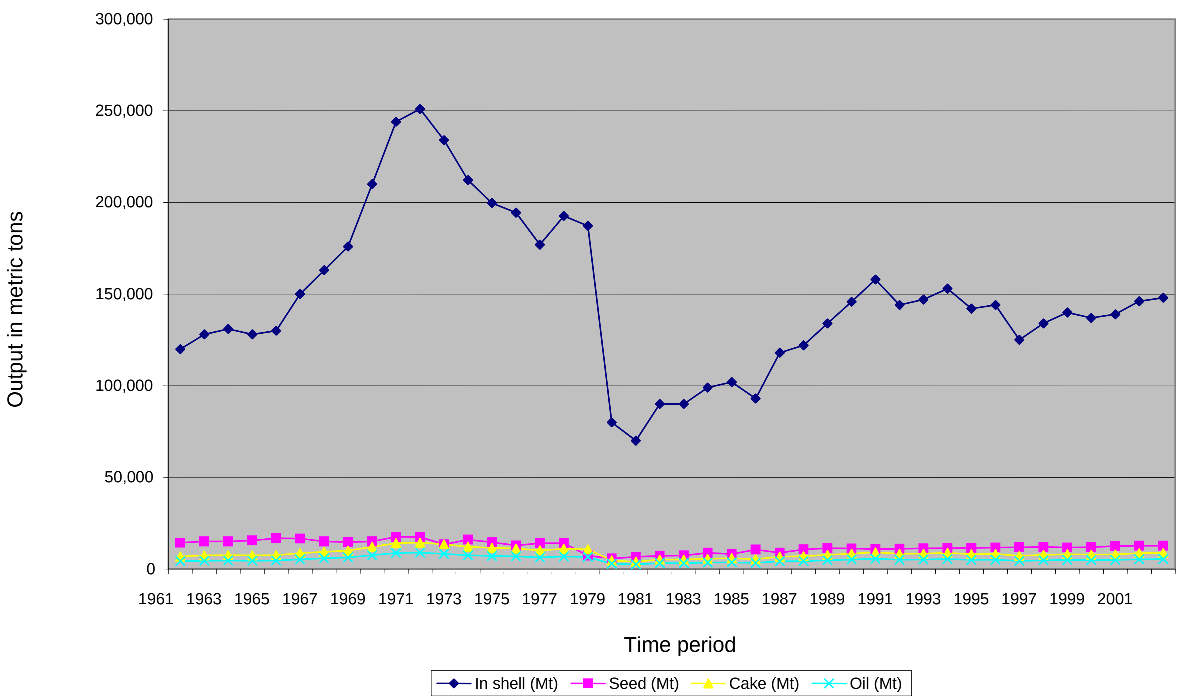
The performance of Uganda's economy at the macro level has been impressive, with real per capita GDP growth since 1995 averaging 6.7 percent, with a rate of 6.6 percent in 2002 and with a projected growth rate of 5.7 percent in 2003. Uganda has approximately 25 million people and currently has one of the lowest (about 5 percent)

HIV/AIDS prevalence rates in Africa (World Fact Book, 2003). Agriculture is the most important sector of the economy, employing over 80 percent of the work force. Coffee accounts for the bulk of export revenues.

Peanut production

Peanut is the second most widely grown legume in Uganda, after beans (Page, et al 2002). There has been a substantial increase in the production of peanuts as both a food and cash crop because of increased awareness of its value as a source of protein (23-25% content) and oil (45-52% content) over a thirty year period starting in the 1960's.

Figure 2.2: Peanut production and processing in Uganda



Over a 40 year period, peanut production in Uganda witnessed a sharp growth in output between 1961 and 1971, after which there was a sharp decline reaching its lowest point in 1980 when only 70,000 metric tons were produced nationally compared 251,000 metric tons in 1971, a 71 percent drop in output (figure 2.2). Post 1980 output recovered steadily and has been somewhat stable between 1991 and 2001 although the volumes are nowhere near the peak 1971 output. Besides in-shell peanuts, Uganda also exports peanut seed, peanut cake and peanut oil, although the volumes for the later three are far less than the in-shell peanuts.

Productivity improvement in peanuts has been slow, constrained by a number of biotic and abiotic stresses such as insect pests, diseases, drought and low soil fertility (Busolo-Bulafu and Nalyongo, 2002). Smallholder farmers are hardest hit by such factors because they lack resources or access to currently available technology to overcome production constraints. In addition, low producer prices and limited marketing opportunities reduce the incentives for producers to invest in productivity enhancing technologies such as improved seed, fertilizer and pesticides. It is partly for these reasons that peanut rosette virus research is a government priority in Uganda (Busolo-Bulafu and Nalyongo, 2002).

The National Agricultural Research Organization (NARO) had been working on Groundnut Rosette Virus (GRV) for years when the Peanut CRSP began work in May 2001 to supplement ongoing research. Peanut research is based at Serere Agricultural and Animal Research Institute in Soroti district in Eastern Uganda, one of the nine government operated agricultural research institutes across the country. There are five improved varieties of peanuts in Uganda currently available to farmers, their maximum on farm trial yields are shown in table 2.3. They are Igola 1 and Serenut 1-4, of which Serenut 1 is the only non rosette resistant variety.

Table 2.3: Peanut varieties of Uganda

	Days to maturity	Yield per hectare- Kg	Average shelling %	Oil content %	Resistance to rosette	Use
Igola 1	120 - 130	2500 - 3000		48.0	High	Confectionery
Serenut 1	100 - 110	2747	72.0	43.9	Low	Confectionery
Serenut 2	100 - 110	2776	69.6	41.9	High	Confectionery
Serenut 3	100 - 105	2747	60.0	47.0	High	Confectionery
Serenut 4	90 - 100	2494	73.0	43.0	High	Confectionery

Source: Busolo-Bulafu, C.M., Nalyongo, P.W. (2002)

Only Serenut 3 and 4 were released after the Peanut CRSP program had been operational in Uganda. Therefore as of summer 2003, these two varieties were the only products influenced by the Peanut CRSP program.

Occurrence of Rosette virus varies from year to year and from season to season depending on rainfall. It is more widespread during drier years as the disease causing agents, aphids, survive better. In wet weather, disease-causing agents are washed off the peanut leaves, and thus never get enough time to establish themselves.

The north, northeast, and eastern parts of the country experience the disease most as they are the main peanut growing areas. These areas include the districts of Apac, Bugiri, Busia, Gulu, Iganga, Jinja, Kaberamaido, Kamuli, Kapchorwa, Katakwi, Kitgum, Kotido, Kumi, Lira, Masindi, Mayuge, Mbale, Pader, Pallisa, Sironko, Soroti, and Tororo.

Poverty in Uganda

Poverty has various dimensions. At the personal level, people may be deprived of adequate nutrition, good health, or education. People may be denied human rights, citizenship, or access to social networks. Cultural values and beliefs may make some people disadvantaged, while a lack of political voice or physical insecurity impoverishes others. Economic factors, such as low incomes, few assets or little access to markets or public services, can force people into poverty. Poverty is also dynamic. Households and people move in and out of poverty over time, even seasonally. Some people are more vulnerable to poverty than others are. A single incident like a cattle raid in eastern Uganda can start a downward spiral. Poverty does not seem to have fallen substantially in Uganda since independence in 1962, although hardcore poverty has been reduced (World Bank, 1996; Jamal, 1998). Poverty also is predominantly a rural phenomenon, with the east and northern regions of the country being the poorest (table 2.4).

Table 2.4: Poverty lines and poverty incidence, Kampala and regions, 1989/90

	Poverty line (Sh. per capita per month)		Poverty Incidence (% of households)	
	Food	Total	Food	Total
Kampala	3990	7980	4	23
Central				
Rural	2730	4095	22	32
Urban	2850	5700	4	12
Eastern				
Rural	2460	3690	31	46
Urban	2850	5700	10	21
Western				
Rural	2610	3915	21	32
Urban	2910	5820	10	21
Northern				
Rural	1590	2385	22	33
Urban	2280	4560	26	32

Source: Jamal V. Changes in poverty patterns in Uganda – in Hansen and Twaddle, 1998.

Uganda is one of the least urbanized countries in Africa with about a tenth of its population living in urban areas compared to about 30 percent in other Sub Saharan African countries (Hansen and Twaddle, 1998).

A 1994 World Bank report, "Many faces of poverty" summarizes the status and changes in poverty in Sub Saharan Africa. Despite the generally poor economic performance of and high increasing incidence of poverty, the link between good macroeconomic policies and lower levels of poverty is evident. Countries that have bad macroeconomic policies indicate an increase in the percentage of people living on less than US$1 a day. At the same time, the report emphasizes the difficulty of measuring poverty in Africa. Few countries are able to provide estimates of income or expenditure distributions for two or more periods in time. In countries for which data exist, the timing of one or more of the surveys may be inappropriate if the reference year is atypical, say a drought year. The report suggests that past household surveys carried out in Uganda had inconsistent methodology and sampling definitions that makes comparison over time difficult.

Studies carried out in Uganda seem to suggest different poverty levels possibly due to methodological aspects of the studies. A 1996 Word Bank country study titled "Uganda: The challenge of growth and poverty reduction", using as its measure of welfare the ratio of household expenditure per adult equivalent to the poverty line, classified 61 percent of Ugandans as poor. The poorest 10 percent were found to consume barely more than one third of the amount consumed by people at the poverty line. Appleton (1998) analyzed income and consumption data from four household surveys carried out between 1992 and 1996 to measure changes in poverty over the four-year period. The study concludes that absolute poverty remained pervasive at the end of the four surveys. However, it did fall quite substantially from 56 percent in the 1992 study to 46 percent in the 1996 study.

Although different studies might not necessarily come up with an exact figure of what the poverty level is for Uganda, it is evident from most that the prevalence of poverty is high (if GDP per capita is less than $300, then logically more than 50 percent of Ugandans are poor) and differs by region. The most affected regions are to the north of the country, which has been a war zone for the past decade, and the east where this study is focused.

It is possible that agricultural research may influence the poverty rate. This influence may occur through several channels, and some of these channels are explored in the next section.

Agricultural research and poverty

Scientists, research administrators and policy makers face increasing pressure to justify continued public investment in agricultural research. As demands proliferate for scarce government funds, evidence is needed to show that agricultural research generates attractive rates of return compared to alternative investment opportunities. The result has been an upsurge in studies, seeking credible ex ante estimates of the expected benefits of current and proposed programs of research and ex post estimates of benefits from previously performed research (Smith and Pardey, 1997; Morris and Heisey, 2003).

The impacts of increased agricultural productivity on poverty are not easy to quantify as they depend on many factors. There may be effects on labor if increased productivity affects labor demand, which in turn may affect both on-farm and off-farm wages. The poor have little land or capital, so they gain disproportionately from employment generated by agricultural growth and from lower food prices, as do the urban poor, who spend most of their incomes on food (Thirtle, et al, 2003). Technology may bring along with it new cropping patterns whose characteristics are difficult to predict, but with effects on household allocation of resources, labor included and thus affecting welfare. Higher productivity resulting from such technologies may also have broad-based multiplier effects within the rural community that might result in employment creation in industries related to the crop, e.g. fertilizer and post-farm, oil making, and roadside marketing.

Considering these factors as a whole, agricultural productivity growth tends to drive pro-poor growth, benefiting poor farmers and landless laborers by increasing both production and employment (Hazell and Haddad, 2001). It benefits the rural and urban poor through growth in the urban and rural non-farm economy. It improves access to crops that are high in nutrients, through lower food prices, and may empower the poor by increasing their access to decision making processes, increasing their capacity for collective action, and reducing their vulnerability to shocks, through asset accumulation (Hazell and Haddad, 2001). However, measuring these myriad effects can be difficult.

Alwang and Siegel (2003) present a relatively simple method of measuring the impact of agricultural research that can be used in research evaluations when there is an interest in assessing poverty effects, once the first round aggregate income effects are measured. That method relies on calculations of changes in poverty rate measures of the Foster-Greer-Thorbecke (FGT) type. Of course, first-round effects, although potentially large, positive and widely distributed for plant genetic improvement research, are themselves subject to many methodological and practical challenges in documentation and measurement (Morris and Heisey, 2003). Problems are associated with measuring adoption and diffusion of hybrid or improved seed, and with apportioning benefits attributable to new hybrid or improved varieties as opposed to other factors. Therefore careful attention needs to be paid to methodological issues.

Chapter 3 presents a methodology followed to achieve the stated objectives. Three major steps can be identified: economic surplus estimation, identification of which households adopt (by income level), and then linking information from the first two steps to changes in poverty.

Chapter 3: Methodology

Introduction

The Peanut CRSP (Collaborative Research Support Program) began in 1982 with funding from the United States Agency for International Development (USAID), through Title XII - Famine Prevention and Freedom from Hunger and authorized under the International Development and Food Assistance Act of 1975. Through its six research thrusts, food safety, production, socio economics, utilization, information and technology transfer, and governance, the program is expected to address sustainability and bio-diversity issues through support of projects that develop plant disease resistance and decrease need for chemical inputs, and that sustain the natural resource base through efficient production technologies.

Peanuts are recognized by USAID as important for development in many areas, including Eastern and Southern Africa. The peanut has an enormous advantage vis-à-vis many other crops in economies at or above the subsistence level in that it has a dual purpose role: it is both a subsistence and cash crop (Smartt, 1994). It is therefore capable of satisfying the food security needs and cash needs of households. Due to the prevalence of peanut viruses in most of Sub Saharan Africa which reduce crop yields, the Peanut CRSP project has sought to:

(i) Develop transgenic groundnut lines with pathogen-derived resistance to groundnut rosette disease and spotted wilt disease;

(ii) Breed naturally occurring resistance to groundnut rosette disease into agronomically important early maturing and/or drought resistant cultivars of *Arachis hypogaea* (peanut); and

(iii) Increase the quantity of seed of high yielding, groundnut rosette disease resistant groundnut, and evaluate the resistant germplasm in Uganda.

The aim of this chapter is to present economic theory and methods that are used in verifying if the objectives of the Peanut CRSP are being realized in Uganda. Given that the main objectives of the study are to estimate the economic impact of the peanut virus research in Uganda and to estimate the impact of Peanut CRSP virus research on the poor, then this chapter develops methods that could help best achieve these objectives.

As a starting point, the impacts of technology on the cost of production at the household level are determined. This information is then used to compute aggregate benefits using the surplus model. Determinants of adoption using household data are then identified. Information regarding the determinants of adoption is then combined with impacts of technology on the cost of production (surplus model) to understand income changes for adopting households. Poverty changes are then computed and comparisons made for households before and after adoption.

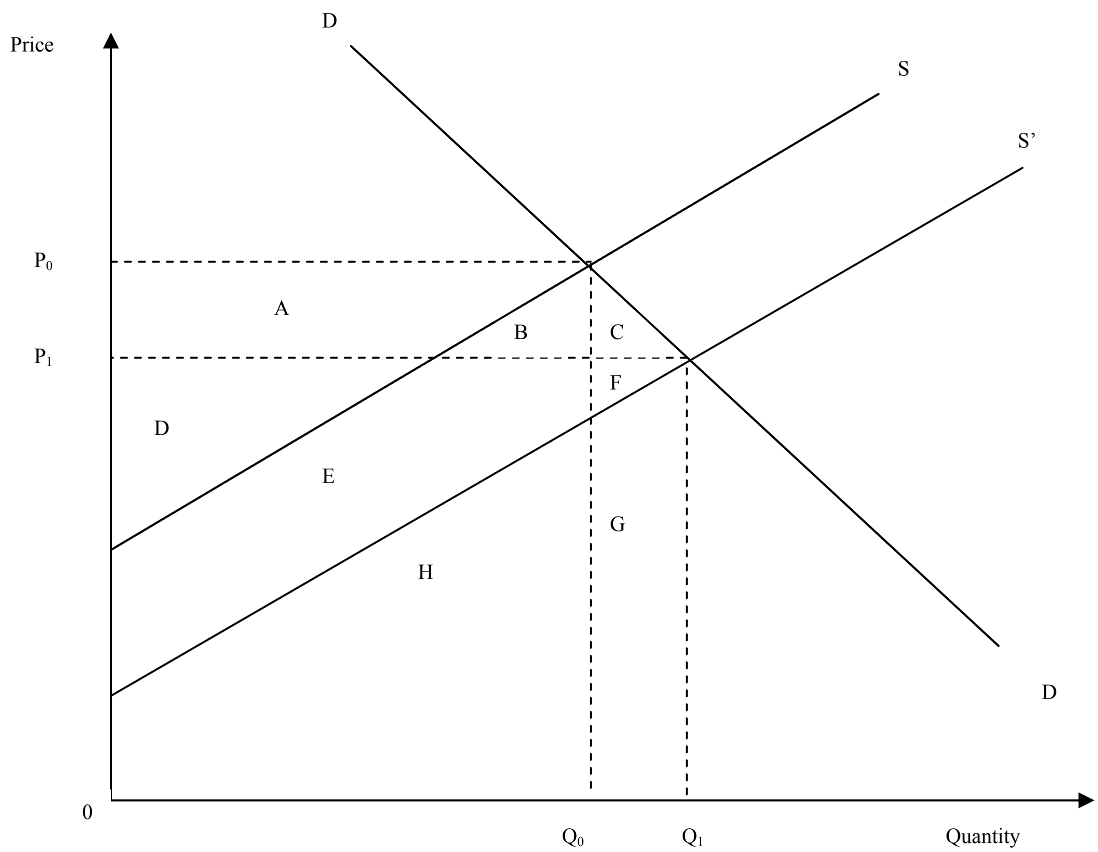
Economic surplus measurement

The concept of economic surplus has been used to evaluate welfare effects of public and private investments (Currie et al, 1971). Surpluses accrue to both buyers and sellers. Consumer surplus is understood in economic theory as “the difference between the sacrifice which the purchaser would be willing to make in order to get it and the purchase price he has to pay in exchange.” It is taken to be the area below the demand curve but above the price line. Economic surplus accruing to producers is defined as the “excess of gross receipts over prime costs”, and for a perfectly competitive industry, it is the area above the industry supply curve and below the price line.

Currie et al (1971) present a basic economic surplus model that has been used to evaluate the effects of poultry research (Peterson, 1967), to estimate the return to investment on hybrid corn (Griliches, 1958) and to compute the return to investment on a mechanical tomato harvester (Schmitz and Seckler, 1970).

Suppose prior to some technological innovation equilibrium price and quantity is P_0 and Q_0 (shown in figure 3.1).

Figure 3.1: Effects of a shift in the supply curve as a result of technical change



Following the development of a new technique, production costs are lowered, shifting the supply curve from S to $S^{'}$. The net social gain is $B + C + E + F$, since the change in producer surplus is $(E + F) - A$, while the gain in consumer's surplus is $A + B + C$.

The exact nature of the supply shift is uncertain. According to Lindner and Jarrett (1978) measurement of gross annual research benefits may produce biased results because of failure to pay sufficient attention to the manner in which the supply curve shifts in response to adoption of a process of innovation by rural producers. Lindner and Jarrett (1978) distinguish between two types of supply shifts, the divergent shift, which includes all cases where the absolute vertical distance between the supply curves is increased as the supply increases (a pivotal and proportional supply shifts are given as two special types of divergent shifts) and the convergent shift. The distinguishing feature between the two is the absolute reductions in average costs, which are greater for marginal firms than for infra-marginal firms in a divergent shift, and the vice versa true for a convergent shift.

Lindner and Jarrett (1978) present evidence that leads them to a conclusion that the measured level of gross annual research benefits is highly sensitive to the nature of the supply shift. This sensitivity is most pronounced when supply is locally inelastic, but even when local supply is highly elastic, making incorrect assumptions about the nature of supply shifts could result in measurement error. Griliches (1958) assumed that yield increased at the same percentage for all producers implying that a proportional supply shift might be applicable to corn. Lindner and Jarrett (1978) argue that not all biological innovations need result in proportionate shifts in the supply function. According to them, in the case of peanuts, nitrogen fixation through rhizobium does not greatly affect yield on soils with an already high nitrogen status, but often has a dramatic impact on low nutrient soils. If low cost producers are on the former group of soils, then the shift in the supply function consequent on this sort of innovation is likely to be highly divergent.

The nature of the supply shift for this study is specified in the following section.

Assumptions of the economic surplus approach

Alston et al (1995) present a set of assumptions, adopted here, that ought to hold for economic surplus measurement to be carried out. Firstly, supply and demand curves are assumed to be linear and to shift in parallel as a result of research induced technical changes. Secondly, a static (multiperiod) model is used and dynamic issues are set aside. Thirdly competitive market clearing is imposed. Also invoked are three postulates (Harberger, 1971) (a) that the competitive demand price for a given unit measures the value of that unit to the demander, (b) that the competitive supply price for a given unit measures the value of that unit to the supplier, and (c) that when evaluating the benefits or costs of a given project, the costs and benefits accruing to each member of the group should be added without regard to the individuals to whom they accrue.

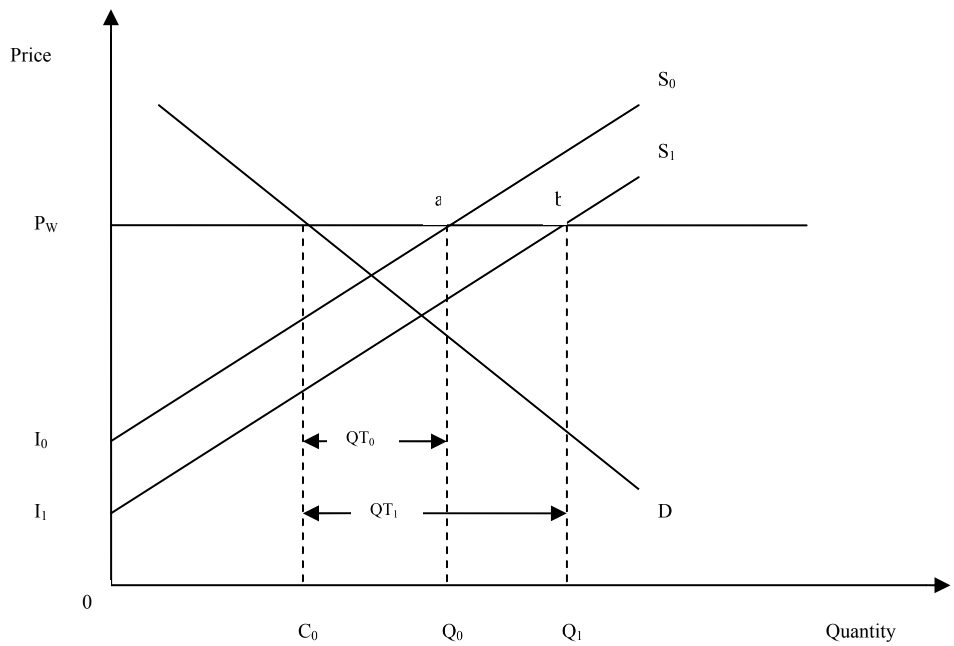
Assumptions about other markets

Ugandan peanuts are tradable although they do on influence international prices significantly. A small open economy model is therefore assumed. The impact of research on a small country exporter of a commodity is illustrated in figure 3.2. The initial equilibrium is defined by consumption, C_0, and production, Q_0, at the world market price,

P_w with a traded quantity QT_0 (representing exports). Research causes supply to shift from S_0 to S_1 and production to increase to Q_1.As a result, exports increase to QT_1. Economic surplus change (equal to area I_0abI_1) is all producer surplus.

There is therefore no effect on the input and output markets as there are no changes in output prices. The technology is the same, what changes is the peanut variety, and thus there would be no increased demand for inputs like fertilizer.

Figure 3.2: Research benefits in a small open economy



Assumption about labor markets

Rosette resistant seed varieties do not have any biases towards or against labor. The technology is therefore neutral to labor. The ability of the new varieties to resist virus attacks and tolerance to drought results in increased peanut yields. Although labor demand is expected to increase, to meet increased harvest needs due to yield increases, the increase is not expected to be large enough to affect the wage rate.

Criticism of the economic surplus methods

One of the main criticisms of economic surplus is tied to one of Harbergers' three postulates, and specifically that when evaluating the benefits or costs of a given project, the costs and benefits accruing to each member of the group should be added without regard to the individuals to whom they accrue. When unequal weights are attached by society to gainers and losers, compensation schemes that assume equal weights will not ensure net welfare gains from technological change (Alston at al, 1995). In reality, farming households have different economic profiles, and technological change may impact on their welfare differently. Therefore to accurately capture the effects of technology it is necessary to take into consideration initial wealth endowments.

Measurement error is another issue critics of economic surplus always refer to. One contentious issue is that consumer surplus holds income constant and yet there are alternative measures, equivalent variation and compensating variation that capture the income affect associated with a price change. Consumer surplus for example, is the excess of the price the consumer would be willing to pay for over the actual cost of the good, equivalent variation (EV), is the amount of additional income that would leave the consumer in the new welfare position if it were possible to buy any quantity of the commodity at the old price. Compensating variation (CV) is the amount of additional income that would leave the consumer in the initial welfare position if it were possible to buy any quantity of the commodity at the new price.

A Shift in the supply curve to the right, against a downward sloping curve, results in lower prices and therefore the real income of the consumer increases, which in effect shifts consumer demand for the good and thereby increasing welfare. As income changes due to price movements, EV and CV become more appropriate measures of welfare as they are better able to capture these changes, although they would require more information.

Producer surplus on the other hand is meant to measure the change in producer welfare associated with a change in economic profit. However, the income effect associated with a change in a factor (or product) price is often substantial, making producer surplus a much less reliable measure of the corresponding equivalent or compensating variation (Alston at al, 1995). Producer surplus may also be thought as not corresponding to the concept of economic profit because it only takes into consideration variable costs. In the production process there are avoidable fixed costs, i.e. costs that do not vary with output, but which can be avoided by not producing. These avoidable fixed costs do affect profit but may not be reflected in producer surplus which only accounts for variable costs.

These are basically some of the main issues that are often alluded to, but as always there are counterarguments, pertaining to data availability, ease of computation and the fact that the gain in precision from using EV and CV might not be large enough to render economic surplus methods completely inaccurate. This probably explains why economic surplus methods are still widely used.

The main intention of identifying any potential shifts in supply is to be able to estimate any economic benefits that might result from the adoption of the rosette resistant seed varieties by farmers in Uganda. If for example the extent by which costs change as a result of adoption is known, this together with income information could help in determining how changes in peanut income impact on household welfare. It is therefore necessary from the outset, that there be an understanding of what the poverty status of the affected households was before adoption of the peanut technology and afterwards. It is for this reason that the next sections explain the methods that are used in identifying adopting households and quantifying the extent of poverty in Eastern Uganda.

Identifying adopting and non-adopting households

Adoption can be defined at two levels, the individual (farm level) adoption and aggregate adoption. Final adoption at the level of the individual farmer is defined as the degree of use of new technology in long run equilibrium when the farmer has full information about the new technology and its full potential. Aggregate adoption is defined as the process of spread of a new technology within a region. Aggregate adoption is a measured by the aggregate level of use of a specific new technology within a given geographical area or a given population (Feder et al, 1985).

To understand better the impact of this research on poverty, it is worthwhile to understand why some households adopt the rosette resistant seed varieties while others do not. The choices in this case are discrete in nature and involve "either-or" situations, in which one alternative or another must be chosen.

Consider a decision maker (deciding on behalf of a household) faced with choosing between two alternatives. If we assume that the household derives a certain amount of utility i.e., income or profits, from each of the outcomes, then it follows that the individual will choose the alternative that provides greater utility. For any household we can observe the alternative chosen and define a discrete (dummy) economic variable as the outcome, $y_i = 1$ if household i adopts the technology and $y_i = 0$ if household does not adopt. If profits from cultivating new varieties (π_a) are greater than profits when households resort to traditional non-rosette resistant varieties (π_{na}), then rational households will respond by choosing to adopt, i.e. $\pi_a > \pi_{na} \Rightarrow y_i = 1$.

The functional form of the probit model is presented (Maddala, 1983) as follows:

$$\Pr ob(y_i = 1) = \Pr ob(u_i > -\beta' x_i) = 1 - F(-\beta' x_i);\ F(-\beta' x_i) = \int_{-\infty}^{-\beta' x_i / \sigma} \frac{1}{(2\pi)^{1/2}} \exp\left(-\frac{t^2}{2}\right) dt$$

Where F is the cumulative distribution for u (the error term). $\beta' X$ is defined as $\beta' X = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + ... + \beta_i X_i + u_i$. X_i is the vector of explanatory variables; u_i is the error term with zero mean and constant variance, i.e., we assume that u_i are $IN(0, \sigma^2)$.

The probit model is then used to predict probabilities of adoption for each household. Households can then be ranked in order of decreasing probability of adoption and "adopting households" can be identified based on the total percentage assumed to adopt.

Poverty measurement

The most commonly used measure of poverty was developed by Foster, Greer and Thorbecke (1984) and is useful because it is additively decomposable with population share weights and therefore allows quantification of poverty for different population subgroups in terms of depth of poverty and its severity, and therefore allowing possible evaluation of effects of agricultural and other government policies.

The FGT class of poverty measures is defined as $P_\alpha = \frac{1}{n}\sum_{i=1}^{q}\left[\frac{z-y_i}{z}\right]^\alpha$, where n is the total number of households, q is the number of poor households, y_i is income or expenditure of the i^{th} poor household (taking income or consumption per capita as the indicator), z is the poverty line and is measured in the same units as is y, and α is a parameter of inequality aversion. When $\alpha = 0$, P_α is the headcount index, which is a measure of the prevalence of poverty or the proportion of the population that is poor. When $\alpha = 1$, P_α is the poverty gap index, a measure of depth of poverty. It is based on the aggregate poverty deficit of the poor relative to the poverty line. When $\alpha = 2$, P_α is a measure of severity of poverty. Each α tells the analyst different things about the patterns of poverty in a population and allows comparison of policies.

The head count index (P_0) (for $\alpha = 0$) is the simplest (and still most common), given by the proportion of the population for whom consumption (or another suitable measure of living standard) *y* is less that the poverty line *z*. For some purposes including analyses of the impacts on the poor of specific policies, the head-count has some serious drawbacks. It is totally insensitive to differences in the depth of poverty.

The poverty gap index (P_1) (for $\alpha = 1$) is a measure of depth of poverty. It is based on the aggregate poverty deficit of the poor relative to the poverty line. Thus a value of $P_1 = 0.1$ means that the aggregate deficit of the poor relative to the poverty line, when averaged over all households (whether poor or not), represents 10 percent of the poverty line. The poverty gap index also has an interpretation as an indicator of the potential for eliminating poverty by targeting transfers to the poor. The minimum cost of eliminating poverty using targeted transfers is the sum of all the poverty gaps in a population. One drawback of poverty gap is that it may not convincingly capture the differences in severity of poverty.

A severity of poverty measure (P_2) (for $\alpha = 2$), unlike the other two, is sensitive to the distribution of income among the poor. It satisfies the "transfer axiom," which requires that when a transfer is made from a poor person to someone who is poorer, the measure indicates a decrease in aggregate poverty.

For both P_1 and P_2 the individual poverty measure is strictly decreasing in the living standard of the poor (the lower the standard of living the poorer you are deemed to be). Furthermore, P_2 has the property that the increase in your measured poverty due to a fall in standard of living will be deemed greater the poorer you are.

Conceptual issues in the measurement of poverty

Choice of poverty indicator

Ideally, we should like a survey based measure that approaches as closely as possible the individual welfare measures of economic theory. Particularly useful here is the concept of money metric utility, whereby the indifference curves of individual preference ordering are labeled by the amount of money needed to reach them at some fixed set of prices, where money metric utility is approximated using real income and real expenditure (Deaton and Muellbauer, 1980).

The choice of poverty indicator could be directed by the research questions being answered, policy implications of the work and availability of data. According to Atkinson (1991), if the concern about poverty takes the form of concern about basic needs, such as food, housing, and clothing, the focus should be on individual items of consumption, and poverty would need to be measured in a multidimensional way, rather than in terms of a single indicator.

If the measure of disadvantage is limited to a single index of economic resources, then a natural choice may appear to be total consumption or expenditure plus home produced goods and services. A household is then considered to be poor if its total consumption is below a specified amount. Most studies record poverty in terms of income rather than consumption (Atkinson, 1991).

Atkinson (1991) details the pros and cons of using income versus consumption. Income rather than consumption is taken as a proxy for living standards because consumption components are hard to quantify. Also, people can always choose a low level of consumption, whereas income is closer to the measure of opportunities open to a household and is not influenced by consumption decisions made. To the contrary consumption is preferred because income may underestimate the level of living. A household that can share in the consumption of others may have higher living standards than income can permit, i.e., when an elderly person living with his or her children benefits from their expenditure. Conversely, income may overstate the level of living when money alone is not necessary to buy the necessary good, for instance, if or if goods are not available, or if there is rationing.

Theoretically, in the context of measuring welfare in developing countries, there is a very strong case in favor of using measures based on consumption not income (Deaton, 1997). Households smooth their consumption over shorter periods of time, days, months, seasons and to some extent years, and yet income, especially agricultural income can be extremely variable. To the extent that income for any time period, say a month, is a poor indicator of the living standard in that month (Deaton, 1997). A better case can be made for annual income, but if farmers can partially smooth out good and bad years, consumption will be a better measure.

At the practical level, the difficulties of measuring income are much more severe than those of measuring consumption, especially for rural households whose income comes largely from self employment in agriculture. Given also that annual income is required for a satisfactory estimate of living standards, an income based measure requires multiple visits or the use of recall data, whereas a consumption measure can only rely on consumption over the previous few weeks (Deaton, 1997). Additionally, people tend to be more sensitive about reporting their incomes in many cases, thus it might be easier for them to report biased figures.

Although consumption and income are the most common measures of welfare, other non-money measures of welfare exist, that could be used in determining poverty status. Examples include nutritional and health status, life expectancy, and education.

Equivalence scales

Traditionally, family income per capita has been used to adjust family incomes according to the number of people in the household. But such an adjustment ignores economies of scale in household consumption related to size and other differences in needs among household members particularly ages of adults and children (Buhmann *et al*, 1988). Efforts to accurately measure economic wellbeing require, among other things, some adjustment of income to take account of need. If, for example, we believe that a household comprised of two adults and three children has different requirements than a household comprised of three adults and two children, we could adjust household income for these two types of households, so as to make them comparable. Equivalence scales are designed to take advantage of this adjustment by taking into account those family characteristics that are deemed to affect need (Buhmann *et al*, 1988).

While it certainly seems likely that household members do not all require the same share of the household's total resources, and that household resources are not allocated equally across all household members, there is no widely accepted alternative to the simple per capita convention (Lanjouw, 1997). Two equivalence scales were therefore utilized in this study, the first one extracted as is from Lanjouw (1997) and the second, only differing from the first in that it incorporates what Buhmann *et al* (1988) refers to as a rule of thumb, which is that additional adults after the first have weights of 0.7.

The justification for using different equivalence scales is that literature (Lanjouw, 1997; Buhmann *et al*, 1988; Coulter *et al*, 1992) suggests that poverty rates tend to be quite sensitive to the introduction of equivalence scales, making it worthwhile to calculate poverty rates several times to see how they change. Table 3.1 presents examples of equivalence scales that are commonly used, and are both employed in this study.

Table 3.1: Equivalence scales used in computing poverty indices

Description	Age category	Equivalence scale A	Equivalence scale B
Infants	Less than 5	0.3 A[2]	0.3 A
Children	>= 5 & < 16	0.5 A	0.5 A
Adults	>=16 & <= 65	1.0 A	1.0A; 0.7A[3]
Elderly	65 and over	0.5 A	0.5A

Source: Lanjouw (1997)

Linking economic surplus and poverty

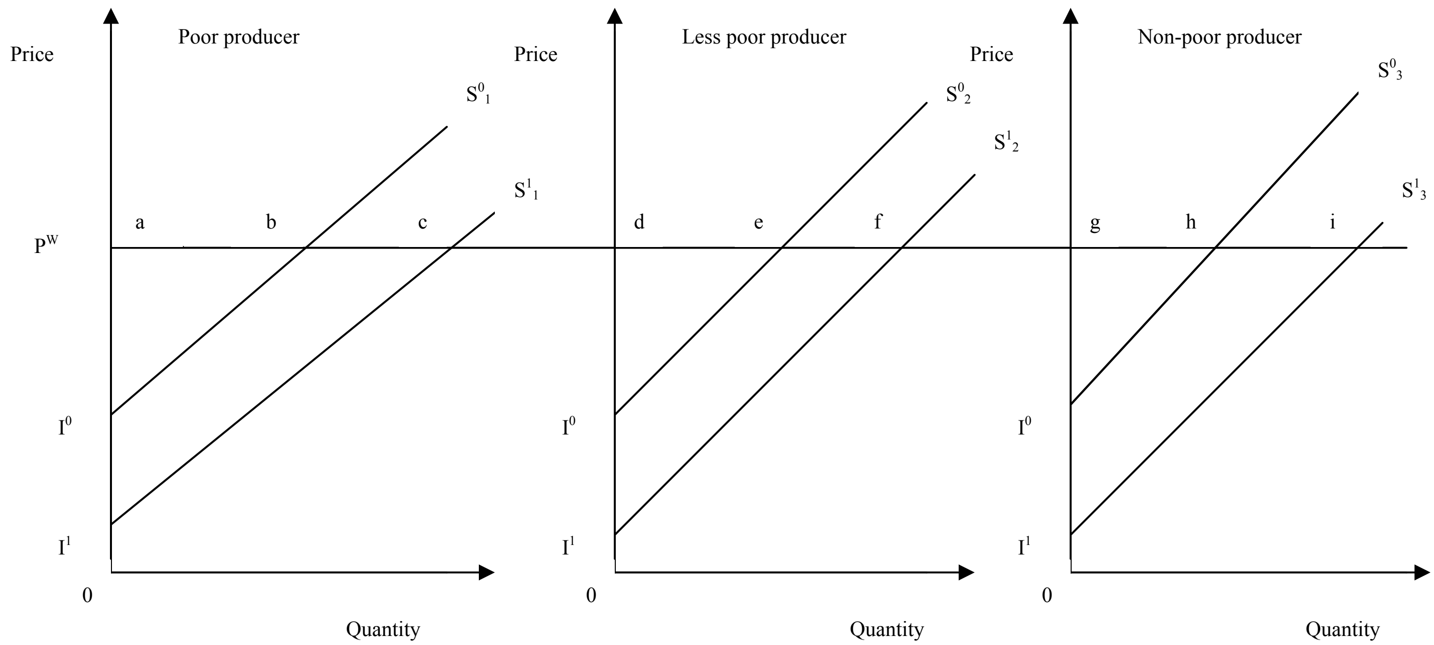
Consider a three-person production economy where the three can be described as poor, less poor and non-poor, each with an individual marginal cost curve, the sum of which gives a market supply curve. Since the model is that of a small open economy, there is no price effect within the economy as total production from Uganda is too small to have an effect on world output. An increase in output, resulting from adoption of new technology is depicted by lowered individual marginal cost curves, which has welfare implications for producers. The net effect on poverty can therefore be estimated by first quantifying the change in profits due to a shift in supply and then using the new income information to determine how affected producers move relative to the poverty line.

Producer surplus is a market phenomenon, while poverty measurement can be more reliably carried out at the individual household level. So the idea is to use

[2] Note that A is an acronym for adult
[3] Additional adults after the first are given a weight of 0.7.

production and cost information to determine the aggregate effects of the research at the regional level and concurrently identify the effects at the household level.

Figure 3.3: Impact of adoption on households of different economic standing



In figure 3.3, P^W is the world price of peanuts, while S^0_j is the supply of peanuts before adoption of new technology and S^1_j is supply of peanuts after adoption of virus resistant peanut varieties for the j[th] producer group. The producer surplus gain can also be referred to as increase in real income of all producers in groups. For a poor producer change in surplus is acI^1 less abI^0, which we can call y^1. For a less-poor producer change in producer surplus is dfI^1 less deI^0, which is y^2, and lastly for a non-poor producer, change in producer surplus is given by giI^1 less ghI^0, which is y^3.

Profit for the i^th producer is given by $\Pi_i = PX_i - \int_0^{x_i} C_i^{'}(X)dX$ where PX_i is the revenue function and $\int_0^{x_i} C_i^{'}(X)dX$ is the area under the marginal cost curve, which represents the variable costs of production. Change in profit as a result of adoption by an individual household is given by, $d\Pi_i = PdX_i - \int_0^{x_i} C_i^{"}(X)dX - dX_i C_i^{'}(X)$[4] where the changes in profits are induced by the K-shift due to adoption. For a three person production economy (representative producers), producer surplus is given by $PS = \sum_i \left\{ PX_i - \int_0^{x_i} C_i^{'}(X)dX \right\}$, which is the sum of the individual household profits.

Conceptually, the change in peanut production and hence income at the household level, as a result of agricultural research should be related to the value of agricultural production, for that particular crop, before the introduction of new technology, and the per unit cost reduction that results after adoption. Alston at al (1995) (p. 226) present a formula that links value of agricultural production with per unit cost reduction (also known as the K-shift), is related to the change in producer surplus. Change in income, (depicted here as y^1, y^2 and y^3) for the i^th household is presented as $\Delta Income = K_i P_i Q_i (1 + 0.5 K_i \varepsilon)$, where P_i is the preresearch price, Q_i is the preresearch quantity, ε is the elasticity of supply, and K_i is the proportionate shift down in the supply curve in a specified period due to research. While producer price and output produced by a household can be found from a household survey, information for determining K_i can be elicited using a survey of 'experts'. Thus we can state that for

[4] This formula is based on Liebnitz's rule for the differentiation of integrals (Kamien and Schwartz, 1981).

every adopting household, $\Delta\Pi_i = \Delta\left\{PX_i - \int_0^{x_i} C_i^{'}(X)dX\right\} \approx K_i P_i Q_i (1 + 0.5K_i \varepsilon)$, since the change in producer income is induced by the K-Shift.

y^1, y^2 and y^3, which are changes in income for representative households, can then be summed to income before technical change (y^0) and plugged into the generic additive poverty measure to compute poverty changes. New household income is then defined as $y^* = y^0 + \Delta Income$. The incidence of poverty after adoption can be computed as $Pi = \frac{1}{n}\sum_{i=1}^{q}\left[\frac{z - y^*}{z}\right]^{\alpha}$. Post adoption poverty levels can then be compared with poverty levels prior to adoption to determine the change in household income.

Density estimation

One of the most reliable methods of tracing the impacts of adopting rosette resistant seed is to plot and compare income distributions before and after adoption. Density estimation is one method that suits this purpose. The probability density function is a fundamental concept in statistics. Consider any random variable *X* that has a probability density function *f*. Specifying the function *f* gives a natural description of the distribution of *X*, and allows probabilities associated with *X* to be found from the relation

$P(a < x < b) = \int_a^b f(x)dx$ for all a < b. Suppose, now, that we have a set of observed data points assumed to be from an unknown probability density function. Density estimation is then a construction of an estimate of the density function from the observed data. Non-parametric density estimation does not assume any underlying distribution for the observed data. Instead data is allowed to ‘speak’ for itself in determining the estimate for *f*. According to Silverman (1986), the basic Kernel density estimator is defined by $\hat{f}(x) = \frac{1}{nh}\sum_{i=1}^{n} K\left(\frac{x - X_i}{h}\right)$ where h is the window width, also called the smoothing parameter or bandwidth, n is the number of observations, and X_i are sample observations on household per capita incomes. This procedure is used for plotting graphs, thus giving a visual impression of the impact of adopting rosette resistant seed by different categories of farmers.

Data

Data for economic surplus estimation

In the data gathering process, a questionnaire was designed and targeted mainly at research managers, breeders, and extension agents who interact with farmers on a regular basis and industry stakeholders e.g., processors of the peanut crop. The questionnaire had four sections. The first one, a personal information section was designed to capture background information about the person being interviewed and the staff compliment of their research unit. The second section was about the peanut CRSP project itself, i.e. information about the history of the project, prevalence of the disease and achievements that had been realized by the time of the interview. Questions in the second section were directed at both research managers and extension workers. The third section was directed at research managers only and it sought to approximate research expenditures for the entire lifetime of the project. The last section was aimed at everyone to document important information that the first three sections might have failed to capture. Data collected through the questionnaire was used to estimate adoption profiles, yield changes and costs of production, all which are essential in estimating economic surplus. A copy of the questionnaire is presented in Appendix 2 of this thesis.

One breeder, responsible for the groundnut improvement program in the whole of Uganda, two extension workers, one a district extension officer in charge of Soroti District, a farm management specialist, and groups of farmers were interviewed in the field. In the City of Kampala, academics were interviewed that carried out research on different groundnut improvement programs, and representatives of organizations that buy and process groundnuts.

Data for poverty estimation

To determine income for Eastern Ugandan households, data from the International Food Policy Research Institute (IFPRI) – Uganda National Household Survey (1999-2000) was used. This survey had three questionnaires, a community survey, crop survey and a socioeconomic survey. Relevant household income data was in the crop and socioeconomic surveys.

The crop survey questionnaire had data on input costs, both labor and non-labor inputs for the whole farm, i.e. not on a per crop basis. To determine the total input costs for the household, input costs for different categories were summed. The crop survey questionnaire lists values of payments to persons engaged in soil preparation, planting, weeding, etc, during the season, for example. These data are summed to determine total expenditures for the i^{th} household. Gross agricultural income is given by multiplying the amount of output produced by the producer price.

The socioeconomic survey questionnaire had data on income from enterprises, employment, and other activities. Income from household enterprises included other agricultural enterprises e.g. livestock, poultry and non-agricultural enterprises. Other income sources consisted of items such as rent, interests, dividends, and income from transfers. Crop farming enterprise data from the socioeconomic survey were omitted as they already had been accounted for in the crop survey questionnaire.

Net household income (NHI) for the i^{th} household, was given by the following formula: NHI = Sum of agricultural income for every crop (Output*Quantity) - total costs of agricultural production + income from household enterprises (e.g. livestock, poultry, cottage industries) + property income (rents, royalties, interests, dividends) + transfers.

Summary

Chapter three described the various methods that were followed in collecting data and making it ready for analysis. It also presented the theoretical justification for the steps that are followed in the research process. An application of these methods is given in Chapter four where the results are presented and then discussed.

Chapter 4 – Results and discussion

Chapter 4 is organized into two distinct but related sections that report the outcomes of stages of the research process. The first section presents the economic surplus model results, while the second identifies farmers most likely to adopt hybrid seed and estimates poverty levels and presents the impact of adoption of rosette resistant seed varieties on their poverty status.

Economic surplus estimation

Data on supply and demand elasticities, production (yield and costs changes), adoption rates, output prices, and research costs were collected. Use of these different types of data in estimating economic surplus is described in detail below.

Years of operation of the project

The National Agricultural Research Organization (NARO) had been conducting research on Groundnut Rosette Virus (GRV) for several years when the Peanut CRSP came on board in May 2001 to supplement ongoing research. This analysis estimates changes in economic surplus for a fifteen year period starting from inception of Peanut CRSP activities in May 2001 through 2015.

Supply and demand elasticities

Many studies have been carried out to determine the responsiveness of supply to changes in prices for a variety of crops. Examples include work by Askari and Cummings (1977), Tsakok (1990) and Rao (1998). Although none of these studies included peanuts in Uganda, a lot can still be learned from them. Rao (1988) states, for example, that crop-specific acreage elasticities range between zero and 0.8 in the short run while long run elasticities tend to be higher (between 0.3 and 1.2). Yield responses to price are smaller and display much less stability than acreage elasticities. Askari and Cummings (1977) emphasize that there is likely to be a wide variation in the quality of the estimates presented in studies of supply responsiveness. Specifically, the differences of definition in the price variable itself, in the price deflators, and in the output measures preclude rigid comparison of elasticity estimates.

Economic theory suggests that agricultural commodities that use relatively little land and few other specialized factors tend to have high elasticities (Alston et al, 1995). The peanut crop in Uganda is in most cases grown on small plots of land by poor farmers using limited resources, in most cases with only seed and labor costs. It is therefore easy to increase or decrease production in the short run in response to changing price incentives. Alston et al (1995) propose that in the absence of adequate information it might be appropriate to assign a supply elasticity of 1 since long run elasticities for most agricultural commodities are greater than one, while short run and intermediate elasticities are usually close to one, and the further from 1, the more erroneous the results of the K formula. Therefore using a supply elasticity of one as a starting point might not be a far fetched assumption, thus this idea is adopted in computing economic surplus for eastern Uganda. The elasticity of demand is assumed to be infinite because Ugandan production is small on a global market scale and the Ugandan economy is relatively open.

Yield and cost change

Based on evaluation data by four Ugandan scientists and other experts of the two varieties of seed involved, Serenut 3 and 4, an average yield increase of 67 percent is assumed[5] (table 4.1). Column three of table 4.1 presents average peanut yields for rosette resistant varieties under normal farming conditions, the numbers in parenthesis are the maximum expected yields under experimental conditions, unlikely to be achieved by farmers.

Table 4.1: Yield changes in Eastern Uganda

Variety	Average yield Kg/ha of non-rosette resistant varieties	Yield Kg/ha of rosette resistant varieties on farm	Percent change
Serenut 3	800	1374 (2747)	71.75
Serenut 4	800	1298 (2494)	62.25
Average			67.00

Source: On farm trial data and opinions of breeders

Conversion of the expected yield change to a per unit cost change was done by dividing it by the elasticity of supply. Input use is expected to increase by 50 percent per hectare upon adopting the technology, mostly due to higher seed costs. This per hectare cost

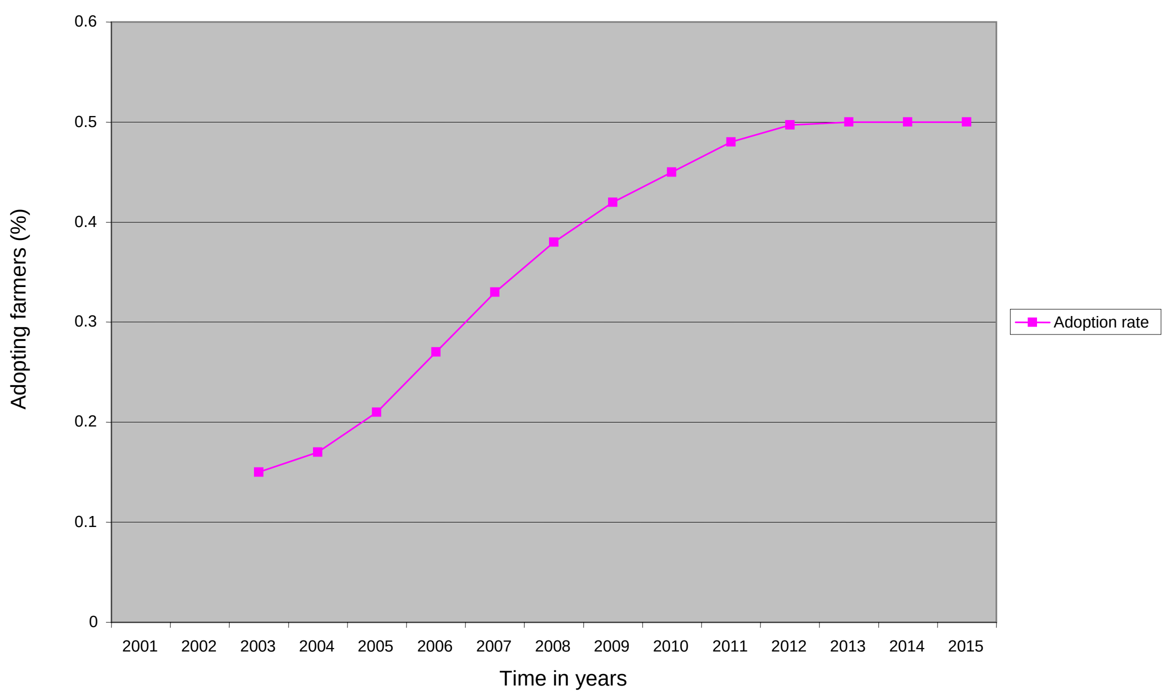
[5] The estimates for yield and cost changes are based on on-farm trial data and opinions of peanut breeders and extension workers.

change was converted to a per ton cost change using the formula in page 380 of Alston, Norton and Pardey (1995), and subtracted it from the per unit cost change due to the yield change to arrive at a net per unit cost change of 37.1 percent.

Adoption rate

At the time of data collection the project had already created a rosette resistant variety, so part of the objective had been achieved. Fifteen percent of farmers were estimated by two extension workers to be using the rosette resistant peanut seed varieties in 2003. For subsequent years, adoption is projected, and is expected to reach a maximum of 50 percent after nine years. The projected maximum adoption rate is based on expert opinion. A plot of the assumed adoption profile is shown in figure 4.1.

Figure 4.1: Rosette resistant peanut adoption profile for Eastern Uganda



Price

Although peanuts are traded, Ugandan production is assumed not to influence world prices because of its low output relative to other producing nations. A three-year average border price for 1999 to 2001 was used as the base price in the economic surplus model. Based on this average, a ton of peanuts was assumed to be worth $750 in 2001, the time of inception of the Peanut CRSP project. This price is used in estimating the economic surplus generated by the project.

Quantity

Quantity produced refers to production volumes specific to the part of the country (Eastern Province) where the evaluation is being carried out. Between the 1999 and 2001 agricultural seasons, Eastern Province districts combined produced an average of 42.8 thousand tons of peanuts. This quantity is used as the base quantity in the estimation. Quantity is also assumed to have an exogenous growth rate of one percent per year, irrespective of the new varieties.

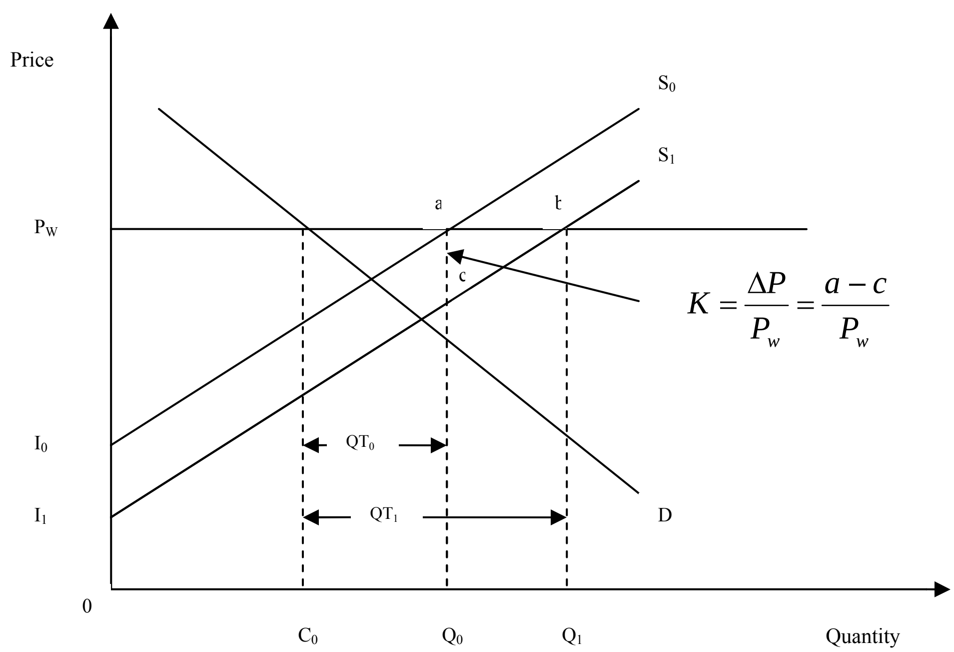
Research cost

USAID, through the Peanut CRSP, will have contributed approximately $56,000 to the project by September 2004. This amount represents only part of the costs. Other costs were incurred by the public sector in Uganda, by ICRISAT in Malawi, and by the University of Georgia. Looking at it from USAID/Uganda perspective, a 20 percent adjustment was made to account for cash inflows from other Ugandan sources, for example to cover salaries of breeders and certain other costs. The total cost (Ugandan plus USAID) of the project is estimated to be about $67,120 or $16,780 per annum, for the four-year period (2001-2004) in which the research was carried out. Other costs incurred by ICRISAT and Georgia need not be considered when calculating the returns on the USAID/Uganda investment but are substantial.

Potential changes in peanut income

With a supply elasticity of 1, the net present value (Total change in economic surplus minus research costs from 2001 – 2015) is projected to be $US 47 million, $38.8 million and $32.3 million at the 3 percent, 5 percent and 7 percent discount rates respectively. These net present values are equivalent to the sum of area I_0abI_1 calculated for each year in Figure 4.2 (minus the research costs which are only in the early years) discounted over the 15 year period.

Figure 4.2: Research benefits in a small open economy



To arrive at changes in poverty rates at the household level, peanut incomes are adjusted upwards by 44 percent for all adopting households, based on the calculations that follow. For every household, change in income, $\Delta TS_i = K_i P_i Q_i \left(1 + 0.5 K_i \varepsilon\right) = 0.371 * P_i Q_i * \left(1 + 0.5 * 0.371\right) = 0.44 * P_i Q_i$. K_i is derived as described above in a spreadsheet for computing economic surplus. (See Appendix 1 for details).

Having determined changes in household peanut income for the Eastern Province, the next challenge is to identify those farmers who cultivate and report income from peanuts that have or are expected to adopt the technologies. It is this group of peanut producers for which the estimated income increases, with potential effects on poverty rates. A binary Probit model is estimated to determine the likelihood of adoption of hybrid seed technology for any crop by all the households (to assess whether adopters are likely to have initially had higher or lower income). Peanut producers are separated by their likelihood of adopting hybrid technology using predicted probabilities. The assumption being made here is that households likely to adopt and use any hybrid seed would also be most likely to adopt rosette resistant peanut seed.

Determinants of adoption of hybrid seed

All the 2949 households in the sample from Eastern Province were asked in the crop survey questionnaire whether they used hybrid or improved seed as opposed to traditional varieties. The responses were binary in nature, yes if they used hybrid or improved seed and no if they did not. Table 4.2 summarizes the characteristics of households that fall into these two categories, i.e., those who used hybrid or improved seed and those who did not.

Table 4.2: Characteristics of adopting and non adopting households

Characteristic	Adopters (N=499)		Non adopters (N=1560)	
	Mean	SD	Mean	SD
Age of household head	43.22	15.46	45.29	16.64
Household size	6.39	3.74	5.53	3.26
Income per capita (UG Shillings)	313,429.73	310,032.76	241,967.25	304,496.43
Land owned per capita (Hectares)	2.90	4.35	2.89	3.88
Number of hoes	3.97	2.74	3.11	2.10
Extension advice	0.61	1.43	0.22	0.81
	N	%	N	%
Male household head	427	85.57	1144	73.33
Married household head	409	81.96	1142	73.21
Highest level of education				
- Primary	261	53.30	844	54.10
- Junior	20	4.01	43	2.76
- Secondary and beyond	135	27.05	224	14.36
Land tenure				
- Freehold	302	60.52	738	47.31
- Customary	160	32.06	745	47.76
Market information received	222	44.49	498	31.92

Fewer households (499) reported that they used hybrid or improved seed, than those that did not (1560). Non adopting households tended to be headed by slightly older people, had a smaller household size, and had lower income and land per capita holdings. Non adopting households were less likely to receive extension advice too, compared to their adopting counterparts. Adopting households were mostly headed by males, who were married in 82 percent of the cases. Adopting households had more (27 percent) people who had some form of post secondary education (university education included) than non-adopting households (14 percent). Most importantly, adopting households had more access to land, on a freehold tenure basis, and were more likely to receive some market information related to crop production and marketing.

The variables used to estimate the probit model were sex and age of household head, marital status, education, extension services, market information, land tenure, household size, income, land holdings and number of hoes owned. Some variables were not continuous, but were dummy variables. These were variables pertaining to sex, marital status, land tenure, market information and education. Results are summarized in table 4.3.

The signs for most of the variables conform to economic theory. For example, a positive relationship is expected between adoption and level of education, access to information, income, and ownership of production resources. The older the household head, the less likely he or she is to adopt hybrid or improved seed as shown by a negative sign on the parameter estimate. Marital status has a negative sign as well, but is statistically non-significant.

Table 4.3: Summary of the binary Probit results

Analysis of Parameter Estimates								
Parameter	DF	Estimate	Marginal Effect	Standard error	95% Confidence limits		Chi-square	Pr > Chi Square
Intercept	1	-2.91770		0.42910	-3.75860	-2.07670	46.24000	<0.0001
Sex	1	0.31070	0.087273	0.09490	0.12470	0.49680	10.71000	0.0011
Age square	1	-0.00010	-0.000015	0.00000	-0.00010	0.00000	5.87000	0.0154
Marital Status	1	-0.09080	-0.027704	0.10030	-0.28730	0.10570	0.82000	0.3653
Highest Education Junior	1	0.24510	0.079561	0.17440	-0.09680	0.58690	1.97000	0.1600
Highest Education Secondary	1	0.28640	0.091620	0.08210	0.12540	0.44730	12.16000	0.0005
Received Advise in 1998	1	0.14640	0.043946	0.03040	0.08700	0.20590	23.28000	<0.0001
Market information 1998	1	0.19180	0.058761	0.06670	0.06110	0.32250	8.27000	0.0040
Land holding per capita	1	0.03060	0.009175	0.03330	-0.03470	0.09590	0.84000	0.3587
Land tenure - Freehold	1	0.28240	0.084520	0.06450	0.15600	0.40870	19.18000	<0.0001
Household size	1	0.02640	0.007912	0.07490	-0.12050	0.17320	0.12000	0.7249
Income per capita	1	0.12170	0.036533	0.03300	0.05700	0.18650	13.59000	0.0002
No of Hoes	1	0.26610	0.079857	0.07040	0.12810	0.40420	14.28000	0.0002

N = 2059; Max-rescaled R-Square = 0.1278; Log-likelihood = -1048.13

Table 4.4: Good ness of fit of the probit model (N = 2059)

		Predicted	
		Adopt	Do not adopt
Actual	Adopt	308	228
	Do not adopt	533	1133

Correct predictions of the model are 1441 (308+1133) out of a possible 2059, which means that probit model is approximately 70 percent accurate.

Male headed households are 9 percent more likely to adopt hybrid or improved seed than female headed households. Households who have junior high school as the highest education achieved are 7 percent more likely to adopt than those households who have primary education as their highest education level achieved. Households with secondary education or higher are 9 percent more likely to adopt new seed technology than those with primary education. An increase in the age of the household head by 1 year results in the probability of adoption decreasing by 2*(0.000015)*(43.45)*100 = 0.13035 %. For logarithmic variables, the marginal effect is divided by the mean, to get the impact on adoption of a unit increase in a variable. An increase in per capita income by a Shilling results in an increase in the probability of adoption by 0.036533/34593.89*100 = $1.055*10^{-5}$ %, a very small change. Similar interpretation applies to the number of hoes, household size, and landholding per capita, which are other variables transformed by natural logarithms.

The Probit results are used to identify farmers who are most likely to adopt new hybrid seed technology. The predicted probability of adoption is used to order the households according to likelihood of adoption. We then apply the income changes from the new technology to the first 15 percent, 30 percent and 50 percent according to adoption probability. All adopting households experience a 44 percent peanut income shift. The number of adopting households increase to 180 at 30 percent predicted adoption and 300 at a predicted 50 percent rate.

Prevalence of poverty among surveyed households

There were 2949 households in the Eastern Province sample that were surveyed as part of the Uganda National Household Survey of 1999-2000. The prevalence of poverty among these households is measured using the FGT measures of poverty using two poverty lines, \$0.50 and \$0.75, and both equivalence scales presented in table 3.1. The results are presented in table 4.5.

Table 4.5: Prevalence in poverty among total sample of surveyed households

	Equivalence Scale A				Equivalence Scale B			
	n poor	\$0.50	n poor	\$0.75	n poor	\$0.50	n poor	\$0.75
Head count Index	1749	0.5933	2215	0.7514	1600	0.5427	2107	0.7147
Poverty gap		0.2690		0.4061		0.2377		0.3722
Severity of poverty		0.1563		0.2617		0.1349		0.2337

Based on equivalence scale A (ESA), and the \$0.50 poverty line, 59.33 percent of the surveyed households are deemed poor. This translates to 1749 households out of 2949 in the sample. For the same equivalence scale but using the \$0.75 poverty line 75.14 percent of the households are deemed poor. A similar trend is observed when analysis is based on the equivalence scale B (ESB). Poverty rates tend to be lower though under ESB, although not by a huge difference. The main difference between these two scales is that in ESB unlike in ESA, additional adults after the first are given weights of 0.7 instead of 1.

In summary the prevalence of poverty among surveyed households varies between 59 percent and 75 percent depending on what poverty line and equivalence scale are used. These poverty levels are only indicative of poverty for both growers and non growers of peanuts before adoption of rosette resistant seed by potential adopters. The next section focuses entirely on the poverty changes only among households that cultivated peanuts.

Impact on poverty of peanut growers

The K-Shift (unit cost reduction from adoption) indicated that adoption of Rosette resistant peanut seed would result in income derived from production of the crop increasing by 44 percent regardless of the rate of adoption. To estimate the impact of this income change on welfare, the three FGT measures of poverty were computed for peanut producing households before and after the adoption of hybrid or improved seed for the three levels of adoption. Two poverty lines were also used, one pegged at $0.50 per adult equivalent and the other $0.75.

Based on the $0.50 poverty line, the headcount index is 0.2556 before adoption and 0.2333 after adoption, which implies that 25.56 percent of the households were poor before adoption and that level of poverty falls to 23.33 percent after adoption (table 4.6). The other indices, poverty gap and severity of poverty also change. The poverty gap decreases from 0.0872 before adoption to 0.0837 after adoption. The severity of poverty decreases from 0.0432 before adoption to 0.0409 after adoption.

Table 4.6: Poverty comparison before and after adoption for different adoption rates (for households included in the survey)

	15 % adoption rate (N=90)				30 % adoption rate (N=180)				50 % adoption rate (N=300)			
	n[6]	$0.50	n	$0.75	n	$0.50	n	$0.75	n	$0.50	n	$0.75
Headcount Index before adoption	23	0.2556	34	0.3778	67	0.3722	96	0.5333	120	0.4000	191	0.6367
Headcount Index after adoption	21	0.2333	33	0.3667	61	0.3389	95	0.5278	112	0.3733	189	0.6133
Poverty Gap before adoption		0.0872		0.1687		0.1217		0.2382		0.1339		0.2702
Poverty Gap after adoption		0.0837		0.1617		0.1143		0.2294		0.1256		0.2592
Poverty Severity before adoption		0.0432		0.0922		0.0582		0.1292		0.0635		0.1435
Poverty Severity after adoption		0.0409		0.0882		0.0542		0.1227		0.0589		0.1358

The sample is representative of households in the region. The 601 peanuts producers in the survey are 20 percent of the households surveyed. Given that there are

[6] Whilst the 'N' in caps refers to the number of households that were at a level of adoption, N=90 for example for 15 percent adoption, the lower case 'n' refers to the number of households who fell below the poverty line for a particular level of adoption.

922,000 households in eastern Uganda, 20 percent of those households are 184,400 households.

This translates into an impact of 614 households ($\frac{2}{601} * 184{,}400 = 613.64$) across the eastern region of Uganda being lifted above the $0.50 poverty line as a result of adopting rosette resistant peanut seed (table 4.6). A similar number of households would be uplifted beyond the poverty line for the $0.75 poverty line. An adoption level of 30 percent implies 180 households in the survey adopt the technology while 421 households do not. The $0.50 poverty line results in a headcount index of 0.3722 before adoption and 0.3389 afterwards.

Six households out of 601 peanut farmers escape poverty due to adoption of the peanut technology, as measured by the headcount index. Region-wide, the impact on poverty is $\frac{6}{601} * 184{,}000 = 1{,}840.93$ households. After increasing the poverty line to $0.75, only 307 households are deemed no longer poor after adopting rosette resistant seed at the 30 percent level of adoption. The other two indices also decrease in value when the before and after scenarios are compared, an indication that household income is on the increase even for those who still remain poor.

As the adopting sample is increased, more marked changes are observed for both poverty lines. As expected, the 50 percent level of adoption results in the greatest impact on poverty, as increased peanut income enables total household income to rise above the poverty line. The headcount index increases as adoption levels are increased, implying that at low adoption rates, the few that are adopting are relatively well-off households.

Table 4.7: Number of households in Eastern Province who escape poverty
(based on head count index as a result of adopting virus-resistant peanut varieties)

Adoption rate	Households escaping poverty	
	Poverty Line: \$0.50	Poverty line: \$0.75
15.00	614	307
30.00	1,841	307
50.00	2,455	614

Considering each of the FGT poverty measures, and the different levels of adoption, it is clear that there is a modest impact on poverty as a result of adopting the new peanut technology. The headcount index might in some cases not indicate significant changes in poverty, but the poverty gap and severity of poverty show for example that a significant number of households are being moved closer to the poverty line, implying that households are benefiting from the availability of Rosette resistant peanut seed.

Non parametric measures of poverty

For a better perspective of the impact of adopting hybrid seed on poverty, non-parametric density estimation was used. In particular Kernel estimators, as described in chapter 3, were used to generate income densities using adult equivalent incomes to make a comparison before and after adoption. Figure 4.4 for example shows four graphs superimposed on each other. One is for income before adoption (All income) and the other three plot incomes after the 15 percent, 30 percent and 50 percent adoption levels. The two vertical lines are the poverty lines.

Figure 4.3: Income densities for all households at different adoption levels

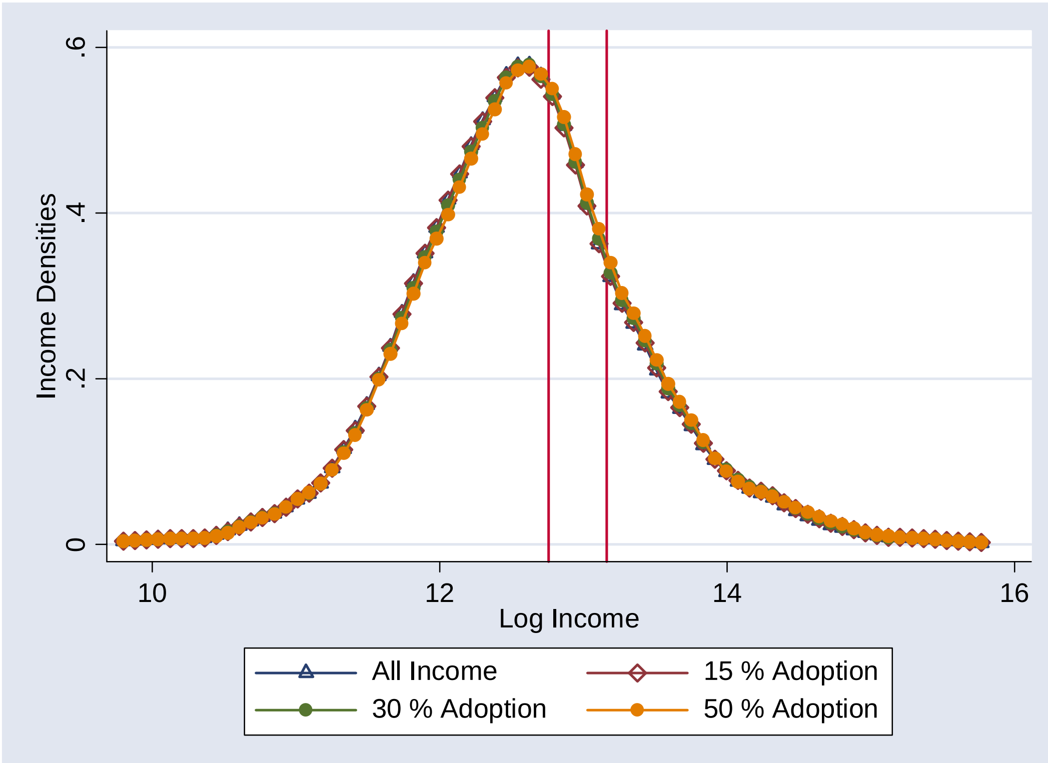
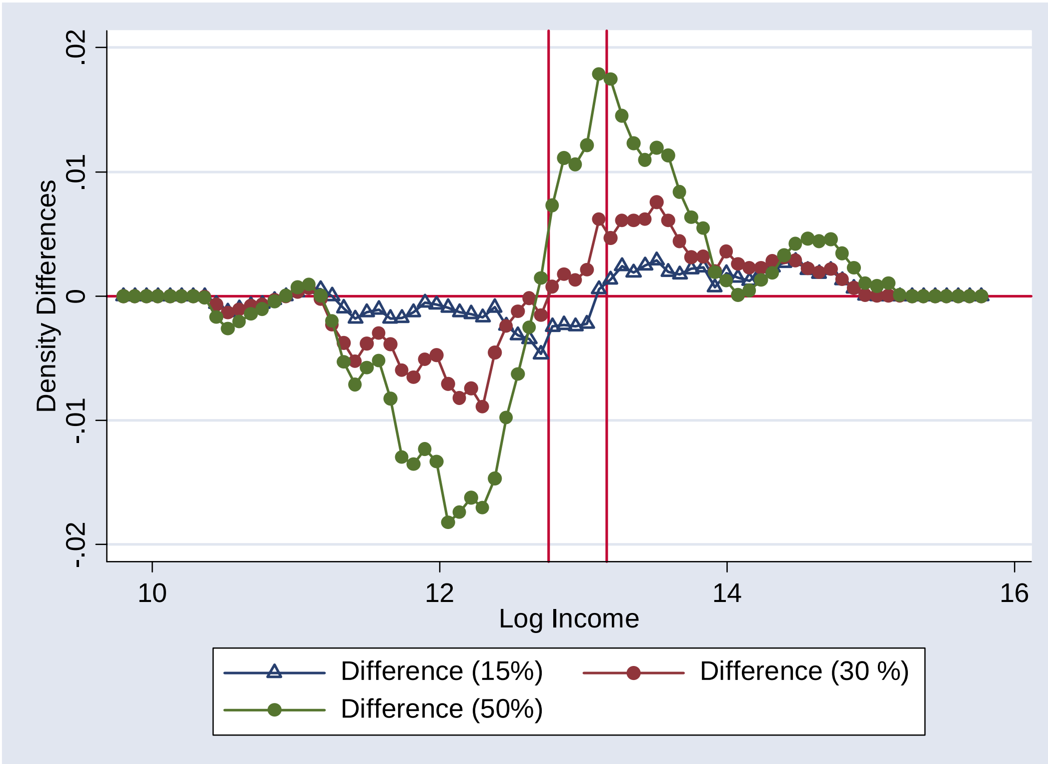


Figure 4.3 shows that there are slight changes in per adult equivalent household income as a result of adoption. Income from peanuts contributes 7.86 percent of household income if we consider all (601) peanut producing households. If adoption rates are factored in the outlook is slightly different. For the top 90 households, those most likely to adopt first (15 percent), peanut income contributes 5.78 percent of total household income and rises to 5.99 percent and 6.53 percent at the 30 percent and 50 percent adoption levels respectively. The main point being emphasized is that peanut income is a small portion of household income, and that is why peanut income changes of up to 81 percent still appear modest.

Density differences are plotted in figure 4.4, and they are the vertical differences between the curves in Figure 4.3.

Figure 4.4: Density differences for households by adoption level



Breaking further apart the density differences to account for different adoption levels, reveals more information. The density differences are closest to zero at the 15 percent, 30 percent and 50 percent adoption levels in that order. This tells us that the least impact on poverty due to adoption of hybrid or improved seed would accrue to those households within the 15 percent level of adoption bracket. The most impact would be felt by those households who lie within the 50 percent adoption level, as it is this level that has the highest proportion of the poorest households of all the three adoption levels. Density differences are greatest at the 50 percent level of adoption for both households below and above the poverty line. All this indicates a change in income profiles of households as those who are slightly below the poverty line are moved closer and in some cases above the poverty line. There is no significant change in density differences for households in both extremes, i.e. the extremely poor and those with highest incomes.

Chapter 5: Conclusions and Recommendations

Summary of results

Results indicate that sizable research benefits are generated by adopting rosette resistant seed varieties. Two years after inception of the Peanut CRSP, rosette resistant varieties developed by ICRISAT were adapted to Uganda and were released. In the same year (2003), they were adopted by 15 percent of the peanut farmers. These benefits are estimated to be $47 million, $39 million and $32 million at the 3 percent, 5 percent and 7 percent discount rates respectively. The adoption pattern indicates that wealthier households (in the sample) tend to adopt first and the poorer, and usually less educated, adopt latter.

Results of poverty prevalence before and after adoption are presented in table 4.6. Ninety households (15 percent) most likely to adopt have a poverty prevalence rate of 26 percent (at the $0.50 poverty line), before any adoption. Poverty rates are more pronounced, up to 40 percent, if the sample of households most likely to adopt is increased to 300 (50 percent). At the $0.75 poverty line, poverty ranged from 38 percent, for the first ninety households most likely to adopt, to about 64 percent when the sample is increased to 300 households. As samples of adopting households are increased from 90 to 300, poorer households are included. Poverty rates drop by about 2-3 percentage points after adoption across all adoption levels.

The poverty gap and a severity of poverty measures show marked changes in poverty, indicating that more households are being drawn closer to the poverty lines (and hence escaping poverty) as a result of adoption. The headcount index indicates that over

2400 households (table 4.7) would rise above the poverty line as a result of adopting the rosette resistant peanut varieties, if 50 percent of them adopt. Poverty is then reduced by a rate of approximately 1.3 percent[7] across the whole of the Eastern Province of Uganda.

Policy implications

As adoption increases, so do the aggregate benefits accruing to the whole region (Appendix 1). Higher adoption rates are tied to greater net benefits due to research and hence increased percent changes in aggregate income. Efforts therefore need to be made to encourage adoption of the rosette resistant peanut varieties. It could be useful to evaluate the effectiveness of current methods of diffusing technology. Recommendations can then be made on appropriate diffusion methods to be followed, and whether more extension agents are needed or not. A decision would be needed about whether agents should be recruited solely for the purpose of peanuts or whether they should be trained for other crops as well.

Results indicate that if adoption was to reach 50 percent, about 1.3 percent of the households in the region would escape poverty. On paper, this poverty reduction may not look large, but considering the fact that peanuts constitute a small percent of the household consumption bundle, the impact is significant. It therefore would appear to be a worthwhile investment if the project or similar initiative could be extended to other regions of the country where peanuts make a sizeable component of people daily lives.

[7] 1.3 percent is given by 2,455 affected households over all 184,400 peanut growing households in the region.

Usefulness of the study

The Peanut CRSP objectives were to develop transgenic groundnut lines with pathogen resistance to groundnut rosette disease and spotted wilt disease; to breed naturally occurring resistance to groundnut rosette disease into agronomically important early maturing and/or drought tolerant cultivars of peanut; and to increase the quantity of seed of high yielding groundnut rosette disease resistant peanuts. Thus, this study evaluated if these three objectives were realized and estimated the impact poverty.

It is known with certainty that resistant varieties were developed and are currently available for use by farmers. The study estimated the extent of adoption, providing an understanding of the profile of adopting and non-adopting households and the impact the project is having on poverty. This information may be of interest to the funding the program.

In a world where resources for agricultural research are limited, there is pressure for projects to become results oriented and to link activities to impact, including impact on the poor. Once a program can demonstrate its ability to meet such objectives it then becomes easier to justify continued funding or to extend the program to other areas facing similar problems.

Further research opportunities

Adoption of technological innovations in agriculture has attracted considerable attention among development economists because the majority of the population of less developed countries derives its livelihood from agricultural production and because new technology seems to offer an opportunity to increase production and income substantially

(Feder et al, 1985). The introduction of many new varieties has been met with only partial success though, as measured by the observed rates of adoption. It is widely believed that there are constraints that slow down adoption, and might involve factors such as lack of credit, limited access to information, aversion to risk, insufficient human capital and many more.

Given this background, for diffusion of the technology to be effective, a proper adoption study would need to be done on actual peanut farmers in the area. If the determinants of adoption can be clearly identified, this could help in devising better targeting methods for diffusing the technology. One of the striking observations in Uganda was that households that are proximal to the research station benefit more than others. Employees of the research station tend to know about new seed varieties earlier, and they were one of the first groups of farmers to use hybrid seeds, highlighting the issue of accessibility. A proper adoption study could also reveal institutional constraints faced by households. Access to credit, for example, could be an issue that affects adoption of hybrid varieties, as these varieties might be more expensive than local varieties. All these, and other institutional issues might have to be addressed for significant adoption to occur.

Poverty is a complicated and elusive concept. In this study, poverty changes are measured using adult equivalent income as a welfare indicator. Also in this study, only households that reported income from peanuts were considered, leaving out those that grew the crop but did not report any income from it. Poor rural households tend to use peanuts for soups, relishes and for sale. According to literature (Smartt, 1994), a significant part of peanuts are consumed by the household, and not sold. For this reason, a more accurate impact of peanuts on poverty could be estimated by measuring their nutritional value.

A nutrition-based poverty study could also better assess intra-household food deficiencies, as females and children are more likely to benefit from harvested food than money income.

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Appendix 1: Computing economic surplus

Year	e	Yield change	Gross prop. cost change	Prop. input cost change	Prop. input cost change per ton	Net chan ge	Adop. rate	K	Price	Quantity	CTS	Cost	Benefit	NPV
2001	1	0.67	0.67	0.5	0.299	0.37	0	0	750	43731.67	0	16780	-16780	48018296
2002	1	0.67	0.67	0.5	0.299	0.37	0	0	750	44168.99	0	16780	-16780	
2003	1	0.67	0.67	0.5	0.299	0.37	0.15	0.055	750	44610.68	1911621	16780	1894841	
2004	1	0.67	0.67	0.5	0.299	0.37	0.20	0.074	750	45056.78	2597522	16780	2580742	
2005	1	0.67	0.67	0.5	0.299	0.37	0.25	0.092	750	45507.35	3308669		3308669	
2006	1	0.67	0.67	0.5	0.299	0.37	0.25	0.092	750	45962.42	3341756		3341756	
2007	1	0.67	0.67	0.5	0.299	0.37	0.25	0.092	750	46422.05	3375174		3375174	
2008	1	0.67	0.67	0.5	0.299	0.37	0.30	0.111	750	46886.27	4126933		4126933	
2009	1	0.67	0.67	0.5	0.299	0.37	0.30	0.111	750	47355.13	4168202		4168202	
2010	1	0.67	0.67	0.5	0.299	0.37	0.35	0.129	750	47828.68	4954640		4954640	
2011	1	0.67	0.67	0.5	0.299	0.37	0.50	0.185	750	48306.97	7335438		7335438	
2012	1	0.67	0.67	0.5	0.299	0.37	0.50	0.185	750	48790.04	7408792		7408792	
2013	1	0.67	0.67	0.5	0.299	0.37	0.50	0.185	750	49277.94	7482880		7482880	
2014	1	0.67	0.67	0.5	0.299	0.37	0.50	0.185	750	49770.72	7557709		7557709	
2015	1	0.67	0.67	0.5	0.299	0.37	0.50	0.185	750	50268.43	7633286		7633286	

Appendix 2: Survey questionnaire

The Economic Impact of Peanut Research on the Poor: the Case of Resistance Strategies to Control Peanut Viruses

Research Evaluation Questionnaire

SECTION A: PERSONELL INFORMATION

Place of interview: Time of interview:

Name of respondent: Organization worked for:

Position of respondent in organization:

Role/duties within the organization:

Length of time involved in the Groundnut Rosette Virus Research:

At which research station are you based?

Which province/district do you cover? Name the place/area?

How many other scientists work with you on the Groundnut Rosette Virus project?

Table 1: Human resources available for the Groundnut Rosette Virus project

	Scientists		Technical support staff	
Research program areas	Number (full time equiv)	Share (%)	Number (full time equiv)	Share (%)
Plant breeding				
Plant protection				
Other				
Commodity total				

SECTION B: PROJECT INFORMATION – Questions in this section are directed at both scientists and extension agents.

1. Where is the project located?

2. When was the project started?

3. How prevalent is Groundnut Rosette Virus?

   a. How often does it occur?

   b. Which areas are most affected (Districts/provinces)?

   c. When did you last have an outbreak, and when do you expect another one?

   d. By how much do outbreaks affect yield per hectare? (It would be useful to look at data for normal vs. years of outbreaks).

Table 2: Average Groundnut yield per hectare over time for affected regions (Normal vs. affected years)

	Year																		
	80	81	82	83	84	85	86	87	88	89	90	91	92	93	94	95	96	97	98
Region A																			
Region B																			
Region C																			
Region D																			
Region E																			
Region F																			

4. Has there been any varieties released already? Name them!

5. Have any technologies from the project been adopted yet? Name them!

Table 3. Adoption profile for different types of farmers and peanut variety adopted

Region	Farm type	Adoption lags		Peanut variety
		Years to max adopt		
		% Max adopt		
		Years to decline		
		Rate of decline		
		Years to max adopt		
		% Max adopt		
		Years to decline		
		Rate of decline		
		Years to max adopt		
		% Max adopt		
		Years to decline		
		Rate of decline		
		Years to max adopt		
		% Max adopt		
		Years to decline		
		Rate of decline		
		Years to max adopt		
		% Max adopt		
		Years to decline		
		Rate of decline		

6. What are the differences in yield that result or are expected to result for those who adopt the technology, by region if possible (Table 4-6).

Table 4. Yield differences induced by "variety 1"

	Region A	Region B	Region C	Region D	Region E	Region F
Yield before technology adoption						
Yield after technology adoption						
Percent yield change						
Adoption rate						

Table 5. Yield differences induced by "variety 2"

	Region A	Region B	Region C	Region D	Region E	Region F
Yield before technology adoption						
Yield after technology adoption						
Percent yield change						
Adoption rate						

Table 6. Yield differences induced by "variety 3"

	Region A	Region B	Region C	Region D	Region E	Region F
Yield before technology adoption						
Yield after technology adoption						
Percent yield change						
Adoption rate						

Table 7[8]. Data from field tests that would help in assessing cost of production with and without the technology (labor, seed costs, pest management costs)

Input	Pre research cost share	Most likely cost change			
		Decrease	No change	Increase	Rate of change
Variable (C/ha)	(%)	(check one)			(%)
Seed cost					
Hired labor					
Fertilizer					
Irrigation					
Fuel					
Other					
Total variable					
Land					

[8] Could be useful for Table 7 to collect gross margin budgets for peanuts before and after the technology was introduced.

SECTION C: RESEARCH COSTS – This section is mostly directed at scientists who manage the groundnut rosette virus project

Table 8. Costs associated with running the groundnut rosette virus project

Year									
No	Date	Capital Costs	Maintenance costs	Operating costs	Full time equivalent	Cost per fte	Total labor costs	Total research costs	Total extension costs
1									
2									
3									
4									
5									
6									
7									
8									
9									
10									
11									
12									
13									
14									
15									

SECTION D: GENERAL INFORMATION

7. What have been or are expected to be constraints to adoption or release of technology?

    a. Institutional: e.g., credit, bio-safety, etc.

    b. Other constraints?

8. What are the alternatives to transgenic resistance?

    a. What was being done prior to technology adoption to limit the problem?

9. Any other comments?

Appendix 3: Summary incomes for households growing peanuts

Summary of incomes for households growing peanuts when adoption is 15 percent

	N	Mean	Minimum	Maximum
Estimated probability of adoption	90	0.5097	0.3872	0.9208
Net household Income	90	3,597,122.82	381,093.76	13,665,609.25
Groundnut Income	90	169,195.56	4,000.00	1,124,000.00
Percent of household income	90	5.78	0.15	36.78
Number of members in household	90	8.39	3.00	24.00
Post adoption income	90	3,671,568.86	384,613.76	13,681,449.25
Income change	90	74,446.04	1,760.00	494,560.00

Summary of incomes for households growing peanuts when adoption is 30 percent

	N	Mean	Minimum	Maximum
Estimated probability of adoption	180	0.4252	0.3039	0.9208
Net household Income	180	2,863,933.02	334,810.75	16,083,460.77
Groundnut Income	180	132,848.61	1,200.00	1,200,000.00
Percent of household income	180	5.99	0.04	45.42
Number of members in household	180	7.96	3.00	24.00
Post adoption income	180	2,922,386.41	336,042.75	16,118,660.77
Income change	180	58,453.39	528.00	528,000.00

Summary of incomes for households growing peanuts when adoption is 50 percent

	N	Mean	Minimum	Maximum
Estimated probability of adoption	300	0.3595	0.2186	0.9208
Net household Income	300	2,309,714.02	334,810.75	16,083,460.77
Groundnut Income	300	115,260.73	1,200.00	1,200,000.00
Percent of household income	300	6.53	0.03	64.87
Number of members in household	300	7.26	1.00	24.00
Post adoption income	300	2,360,428.75	336,042.75	16,118,660.77
Income change	300	50,714.72	528.00	528,000.00