Peanut Research and Poverty Reduction: Impacts of Variety Improvement to Control Peanut Viruses in Uganda

Sibusiso Moyo, George W. Norton, Jeffrey Alwang,

Ingrid Rhinehart, and C. Michael Deom*

Abstract

A procedure is developed and applied for predicting ex ante impacts of agricultural research on aggregate poverty, using as an example the poverty-reducing impact of peanut research in Uganda. Market-level information on economic surplus changes is combined with a procedure for allocating income changes to individual households. Characteristics of farmers that affect their likelihood of technology adoption are used to create a technology adoption profile. Associated changes in poverty resulting from adoption are computed using poverty indices. Predicted income changes at the household level are aggregated to the market level and reconciled with calculations of economic surplus changes.

Keywords: Poverty impacts of agricultural research, Rosette virus, Uganda peanuts,

Running Head: Poverty Reducing Impacts of Agricultural Research

Sibusiso Moyo, George W. Norton, and Jeffrey Alwang are former graduate research assistant, professor, and professor respectively at Virginia Polytechnic Institute and State University, Blacksburg, Virginia 24061. Ingrid Rhinehart is research analyst, International Food Policy Research Institute, Washington, DC. Michael Deom is professor, University of Georgia. The authors would like to thank Charlene Brewster, two anonymous reviewers and the Journal Editor for comments and Charles M. Busolo-Bulafu for supplying data and information and helping with logistics during information collection in Uganda. The financial support of the USAID through the Peanut CRSP and IPM CRSP (LAG-G-00-93-0053-00) is gratefully acknowledged.

Peanut Research and Poverty Reduction: Impacts of Variety Improvement to Control Peanut Viruses in Uganda

Scientists, research administrators, and policy makers face increased pressure to justify public investments in agricultural research. As demands grow for scarce funds, evidence is needed to demonstrate that agricultural research generates attractive returns compared to alternative investments. The result has been an increase in studies projecting benefits of current and proposed research and estimating benefits of previous research (Smith and Pardey 2003; Morris and Heisey 2003). Research managers also feel increased pressure to direct publicly funded agricultural research toward the needs of small-scale farmers and the poor. Policy makers call on research managers to explicitly consider poverty reduction objectives in resource allocations (Byerlee 2000; Alwang and Siegel 2003).

Agricultural research can significantly influence the level and the distribution of income and can reduce poverty in several ways. Technology adoption can lower per-unit cost of production, increase the supply of food, and raise incomes of adopting producers. Outward supply shifts can lower food prices to the benefit of consumers, while producers, particularly late-adopters, may lose. Depending on the input bias of the technical change, input demands may change. Increased labor demand may raise wages, including earnings of poor laborers. The poor also gain disproportionately as consumers from lower food prices, as they spend a high proportion of their income on food (Thirtle, Lin, and Piesse, 2003). Technological changes may bring new cropping patterns whose characteristics are difficult to predict. Higher productivity could also create broad-based multiplier effects within the rural community, inducing employment creation in industries related to agricultural production, such as value-added processing, and roadside marketing. These distributional effects are theoretical, and net impacts on the poor of agricultural research are case-specific and require empirical quantification.

This article develops and applies a procedure for predicting the impacts of agricultural research on poverty levels, examining the poverty-reducing impact of peanut-disease-resistance research as an example. Our procedure combines market-level information on economic surplus changes with a procedure to allocate income changes to individual households. We examine the characteristics of farmers affecting their likelihood of technology adoption and use this information to create a technology adoption profile. Associated changes in poverty resulting from adoption are computed measures of the Foster-Greer-Thorbecke (FGT) type (Foster, Greer, and Thorbecke 1984). Calculations of predicted income changes at the household level are aggregated to the market level and reconciled with market-level calculations of surplus changes. This new technique, which uses additional economic analysis to exploit the link between economic surplus changes and aggregate poverty rates, will be of interest to policy makers and others interested in understanding the impact of agricultural research alternatives on poverty reduction.

Despite increased interest in understanding poverty impacts of agricultural research, few ex ante studies of impacts of agricultural research on aggregate poverty have been conducted. Widely used ex ante assessment tools, such as economic surplus analysis, can be disaggregated by region and for population subgroups to examine the distribution of research impacts on groups such as households in lower expenditure quintiles, by region, etc.

All these findings support the notion that research benefits are unevenly distributed. Impacts on household-level and aggregate poverty are considerably more difficult to measure or predict, primarily because poverty status is household-specific while most surplus measurement is conducted at the market level. In an ex ante setting, research-induced shifts in the aggregate supply function lead to market-level surplus changes; such shifts are caused by decisions made by individual farmers to adopt and the subsequent impact on their marginal cost of production. The market-level economic surplus approach requires, among other things, estimates of technology adoption, which may vary by region, by household conditions and other factors. Thus, the market-level approach cannot yield measures of poverty changes without a system for allocating market surplus changes to individual households.

Agricultural Research and Poverty in Uganda

Rural households in Sub-Saharan Africa depend heavily on agriculture, with peanuts the principal source of digestible protein, cooking oil, and vitamins in many African countries. Peanut productivity has a significant impact on the economic and nutritional well being of a large segment of the population. Unfortunately, peanut production is affected by several viruses and diseases, the most common being Groundnut Rosette, a viral infection first reported in Tanzania in 1907 (Gibbons 1977). Groundnut Rosette has caused devastating losses to peanut production in Africa. The Rosette epidemic in 1994-1995 in central Malawi and eastern Zambia destroyed the crop; groundnut area in Malawi fell from 92,000 ha in 1994-1995 to 65,000 ha in 1995-1996 and losses in Zambia were estimated at US$ 5 million in 1995-1996. Overall losses due to Rosette in Africa were estimated at about US$ 156 million per annum (ICRISAT 2005).

Peanut varieties with (partial) resistance to Rosette virus have been developed for Uganda,[1] a country where most people earn less than US$ 1.00 per day and rural poverty is pervasive (World Bank 2006). While peanuts are not as important to diets in Uganda as they are in West African countries, they are important in certain sub-regions, particularly in Eastern Province, the focus of this study.[2] Research leading to a virus-resistant variety in Uganda may have significant economic benefits, and importantly, reduce poverty.

The distribution of benefits from Rosette-resistant peanut varieties may be biased toward the poor for several reasons. First, peanuts are mainly produced by small-scale farmers in Sub-Saharan Africa, most of who are poor. Productivity gains may raise incomes among adopters, possibly lifting poor families above the poverty line. Second, peanut seeds are regularly purchased even by poor farmers since stored seeds lose their productive potential over time. The need to purchase virus-resistant seeds may not represent a significant barrier to adoption if production costs per unit of output for resistant varieties are lower than for traditional varieties. Finally, groundnuts represent an important consumption item in poorer households, allowing them to capture benefits of price reductions that may occur as research induces supply shifts.

Methods

Economic surplus analysis is combined with household-level data analysis to construct ex ante estimates of changes in poverty resulting from adopting virus-resistant peanut varieties. The surplus analysis provides estimates of changes in prices and economic surplus under various assumptions about technology adoption. The household-level analysis uses consistent information about changes in production costs associated with adoption and consumption patterns to infer household-specific changes in income; it allocates economic surplus to individual producers and consumers. With appropriate survey weights, household income changes can be used to estimate changes in aggregate poverty and changes in aggregate income, which, in the context of the model, should be consistent with findings from the market-based surplus analysis.

Economic Surplus Analysis

Standard approaches to ex ante estimation of research impacts involve several steps: (i) calculating a k-shift, representing the unit-cost reduction associated with use of a new technology; (ii) gathering information on expected adoption rates and their evolution over time; (iii) combining (i) & (ii) with market-related information on supply and demand elasticities and equilibrium prices and quantities (Alston, Norton, and Pardey 1985). These steps allow estimation of price, quantity and corresponding economic surplus changes associated with technology adoption. Modifications to the techniques include efforts to distinguish among producer groups, who may vary in propensity to adopt different technologies (Mutangadura and Norton 1999), regional variation to reflect spatial differences in cost, shipping, prices and markets (Mills 1997), and regional differences in productivity (Karanja, Renkow, and Crawford 2003). The challenge then is to allocate the economic surplus to specific households.

Changes in economic surplus can be calculated under various market situations. For example, in a small open-economy, the primary beneficiaries from adopting a cost-reducing technology are the peanut producers, either through sales or home consumption (figure 1). The initial equilibrium is defined by consumption C_0, and production Q_0, at the world market price P_W, with export quantity QT_0 equal to the difference between consumption and production. Research lowers the unit cost of production, causing supply to shift from S_0 to S_1 and production to increase to $Q_{1,}$ with exports increasing to QT_1. Economic surplus change is equivalent to producer surplus change and is equal to area I_0abI_1. If prices in all other markets (for example, labor markets) are unaffected by the supply shift, then the surplus change captures the entire short-run benefits of adoption. In cases where other prices change, additional analysis is needed; a multi-market model is one example of such an analysis (Karanja, Renkow, and Crawford 2993; Renkow 1993). If the price of the product in question changes, due to a less than infinitely elastic demand, then changes in consumer surplus must be computed as well (figure 2).

Poverty Changes: Allocating Surplus to Households

Analyses of predicted changes in poverty resulting from adoption of a new technology involve three main steps: (i) computing the household-level value of the welfare measure (income or consumption per capita) and comparing it to the poverty line; (ii) determining which households are most likely to adopt the technology and estimating how household welfare will change following adoption; and (iii) adding up the change in the number of poor people or households resulting from adoption. The household analysis of ex ante income changes among adopting households can be used to create an estimate of market-level surplus changes (corresponding to the total change in income for all participants in the market) and of changes in poverty in the population.

The FGT indices are a commonly used means to add up poverty in a population and are useful because they are additively decomposable with population share weights (Ravallion 1992). Additive decomposability allows evaluation of impacts of agricultural and other policies on sub-groups (such as peanut producers). 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 people, q is the number of poor people, y_i is income or expenditure of the i[th] poor household, z is the poverty line, measured in the same units as y, and α is a parameter of inequality aversion[3].

Survey data on household production and income allow estimation of poverty rates, and our study examines how adoption of a new technology changes those rates. The correspondence between the economic surplus approach and the household approach comes from the change in marginal (unit) cost of production caused by adoption of the technology. Farm profits for the i[th] household are given by:

(1) $$\pi_i(\tau) = PX_i - \int_0^{X_i} C_i^{'}(X,\tau)dX$$

where τ is a technology shifter, PX_i represents revenues and the right-hand integral is the variable costs of production (C'(X, τ) is the marginal cost function). Adoption of the technology causes profits to shift by

(2) $$d\pi / d\tau = X_i \frac{\partial P(\tau)}{\partial \tau} + P\frac{\partial X(\tau)}{\partial \tau} - \int_0^{X_i}\frac{\partial C'(X,\tau)}{\partial \tau}dX - C'(X)\frac{\partial X(\tau)}{\partial \tau}$$

where Leibnitz' rule is used to compute the derivative in (2). In an open economy case, the first term on the right-hand side of equation 2 is zero, and the change in profits is equivalent to the surplus (I_0abI_1) in figure 1 in a single-producer economy. To see this, note that the second term on the right-hand-side of (2) is equal to abQ_1Q_0 in figure 1. The third term is acI_1I_0, and the fourth term approximates cbQ_0Q_1 for small changes. Summing over the total number of producers in the region leads to equivalence between the measure of change in individual farmers' profits in equation 2 and the area of surplus change in figure 1.

The change in peanut production and household income as a result of agricultural research is related to the value of agricultural production before adoption of the new technology, and the per unit cost reduction that results from adoption. The same k-shift as used in the surplus analysis can also be used at the household level to approximate $d\pi_i(\tau)$. For the i^{th} household, in the small open-economy case, the change in surplus (income) is

(3) $$d\pi_i(\tau) \approx K_i P_i Q_i \left(1 + 0.5 K_i \varepsilon\right) = I_0 ab I_1,$$

where P_i is the pre-research price, Q_i is the pre-research quantity, ε is the elasticity of supply, and K_i is the proportionate shift downward in the marginal cost curve due to research. Adopters of the technology receive this income benefit; the market K-shift shown in figure 1 incorporates assumptions about rates of technology adoption.

In a closed-economy, or in cases where regional prices respond to changes in market conditions, prices are expected to decline in response to a research-induced outward shift in supply (figure 2). In this case, there are three distinct components of surplus: a loss in producer surplus for all producers due to the price decline (represented by the first component of equation 2, and P_0acP_1 in figure 2), an increase in producer surplus among adopting farmers due to the lower cost of production (the second-fourth components of equation 2, and P_1bI_1 less P_0aI_0 in figure 2), and a gain to consumers due to the price decrease (P_0abP_1). These three components of surplus must be allocated to specific households according to whether they produce peanuts, whether they are likely to adopt the new technology, and whether they consume peanuts.

To assign producer surplus change to each of the households, total peanut production was computed and producer surplus change was assigned according to a household's production share and its probability of technology adoption. Consumer surplus was allocated in a similar manner: assign total surplus to households based on how much an individual household consumed, including home consumption.

The model is general enough to measure changes associated with product and input price changes. In each case, the relevant participants in the markets must be identified and the corresponding surplus allocated to individual households. In our empirical example, we first focus on allocating producer surplus in a small open-economy, then on the change in consumer and producer surplus in a closed economy.

Household-Level Adoption

Since we desire ex ante predictions of poverty change, it is necessary to identify farmers who are likely to adopt hybrid or improved varieties in order to implement equation (3) (and a corresponding equation for the closed economy case). A model of adoption probabilities can be estimated to identify households most likely to adopt the new technology. One means of modeling adoption is to assume that farm decision makers face two alternatives—adopt or not, with the decision based on expected profits associated with each alternative, perceptions about risks, availability of information, and household-specific constraints.[4] The adoption probability for each household can be predicted given observations on the adoption of similar technologies and variables affecting the probability of adoption. Households can then be ranked in order of decreasing probability of adoption and "adopting households" can be identified as those whose predicted probability of adoption exceeds a threshold prediction probability. If it is assumed, for example, that 30 percent of households adopt, those households are selected whose predicted probability of adoption exceeds that of the household at the 70th percentile of our ranking. This approach is similar to propensity score matching techniques (e.g. Gotland, et al. 2004).

In an ex ante setting, no information is available from households on adoption of the specific technology of interest. The adoption probability index can be estimated using observations on adoption of an observed alternate technology, such as hybrid seed or fertilizer. Adoption profiles for hybrid seeds are likely to be different from those of new peanuts due to differences in capital requirements, seeding rates, etc. However, the assumption we make is that past adoption propensities of any new technology are good indicators of those households most likely to adopt in the future.

Data and Results

Economic surplus results are presented first, followed by the results of how that surplus is allocated to individual households, and the impact on household income changes and poverty. Data for calculating the poverty indices and the adoption model were obtained from a national household survey conducted by the International Food Policy Research Institute (IFPRI) in collaboration with the Uganda Bureau of Statistics through the Uganda National Household Survey (UNHS) project of 1999/2000. The data set contains

2949 households in the peanut growing region, enabling computation of the poverty indices and providing information on socio-economic characteristics affecting technology adoption. A crop survey, a socio economic survey, and community survey questionnaires were all included. Information was obtained on household demographics, assets, labor allocation, yields and costs, and other agricultural production information. The surveys targeted representative households across Uganda (UNHS).

Economic Surplus Estimation

Data on expected yield and cost changes following adoption of the Rosette-resistant technology, and expert-opinion on expected adoption rates were obtained during a visit to Uganda in July 2003. A breeder responsible for the groundnut improvement program in Uganda, two extension workers, one a district extension officer in charge of Eastern Province, a farm management specialist, and several farmers were interviewed. University scientists conducting groundnut improvement research and buyers and processors of groundnuts were also interviewed. A questionnaire was designed and targeted at research managers, breeders, and extension agents who interact with farmers on a regular basis (Moyo). Questions were asked about groundnut research expenditures in Uganda, and expected adoption profiles, yield changes, and costs of production.

Information was collected on current peanut yields and costs of production for traditional and virus-resistant varieties (Serenut 3 and 4) as well as realized and projected adoption rates. The varieties were released in 2001 and therefore there was already some adoption (15 percent in the first two years) and higher adoption was expected in the coming years (experts estimated a maximum adoption rate of 50 percent). The Ugandan

National Agricultural Research Organization (NARO) had been conducting research on Groundnut Rosette Virus when the Peanut CRSP (funded by USAID through the University of Georgia) brought the new virus-resistant variety, developed by ICRISAT in Malawi, to Uganda. Our analysis begins by estimating net returns from this research for a fifteen year period starting from inception of Peanut CRSP activities in May 2001.

Parameters in the Surplus Analysis

Parameters for the economic surplus analysis were obtained from existing data and from expert opinion as indicated above. The model results can be sensitive to assumptions, and therefore sensitivity analysis was completed for elasticities, the adoption profile, and the discount rate. It would be straightforward to conduct sensitivity analysis on costs of the different groundnut technologies, about which there might be uncertainty.

A groundnut supply elasticity was not available for Uganda. Theory suggests that annual commodities using relatively little land and few other fixed factors will have relatively high elasticities of supply. Alston, Norton, and Pardey (1995) suggest that without other information, a supply elasticity of 1 is a good starting point since long-run elasticities for most commodities are greater than one, while short-run and intermediate elasticities are often close to one. We assume it is one. The demand elasticity is assumed to be -0.5, as groundnuts are a staple crop but preferred to many low cost starches.

Based on opinions of Ugandan scientists and other experts and on evidence from farmers who had already adopted, it is estimated that yield will increase by 67 percent following adoption (Moyo 2004). Input use is expected to increase by 50 percent per hectare upon adopting the technology, due to higher seed and other costs.

This per hectare cost change was converted to a per ton cost change and subtracted from the yield effect using the formula $K_t = \left[\frac{E(Y)}{\varepsilon} - \frac{E(C)}{1+E(Y)} \right] pA_t(1-\delta_t)$ (Alston, Norton, and Pardey, 1995, p. 380) to arrive at a net per unit cost change of 37.1 percent. A three-year average border price for 1999 to 2001 was used as the base price in the economic surplus model, or $750/ton. Between the 1999 and 2001 agricultural seasons, Eastern Province farms produced an average of 43 thousand tons of peanuts (UNHS 2001), and this amount was used as the base quantity.

USAID, through the Peanut CRSP, contributed $56,000 to the project, and other costs were incurred by the public sector in Uganda, by ICRISAT in Malawi, and by other U.S. universities. A 20 percent adjustment was made to account for Ugandan costs, including the salaries of breeders and other costs. The total cost (Ugandan plus USAID) was estimated to be $67,120 or $16,780 per annum, for the four-year period (2001-2004) in which the research was conducted. Other costs incurred by ICRISAT and Georgia were not included when calculating returns on the USAID/Uganda investment.

Aggregate Changes in Net Economic Benefits

The net present value of the research over the 15-year period for the open-economy model is estimated to be $US 43.0 and $35.6 million at 3 and 5 percent discount rates, respectively. These estimates represent aggregate net returns to the research. The gross benefits accrue to producing households in the Eastern Province, and the costs are borne by the research sponsors. In the closed-economy case, net benefits are estimated to be $US 41.1 and $34.0 million at 3 and 5 percent discount rates, respectively. In the closed-economy case, the gross benefits accrue to producing and consuming households.

These estimates do not, however, indicate how poverty will change as a result of the research. Changes in poverty clearly depend on the characteristics of adopting households along with the per-household change in producer and consumer surplus.

Household-Level Incomes and Changes in Poverty

Poverty in Eastern Province is high, with the depth and severity indices indicating a significant shortfall in income below the poverty line and a high degree of inequality among the poor. Members of peanut-producing households are less poor than those in the full sample; the headcount of poverty is about 4 percentage points lower (table 1). The depth and severity indices indicate that peanut-producing households are more homogeneous than the full sample, as the percentage point gap between peanut producers and the full sample is higher for the depth and severity indices as compared to the headcount index. Poverty is much deeper and more severe among the non-producing households than the headcount index alone indicates.

Determinants of Adoption of New Technologies

All 2949 Eastern Province households in the survey were asked about use of hybrid or improved seed but only 2059 responded. Such seeds were adopted primarily for maize, but were adopted as well to a lesser extent for several other crops, including peanuts. Fewer households (499) reported using hybrid or improved seed than not using (1560). Non-adopting households were headed by slightly older people, had fewer members, and lower income (table 2). Non-adopters were less likely to receive extension advice than adopters. Adopting households were mostly headed by married males. Adopting households had more (27 percent) people with post secondary education than non-adopting households (14 percent). Adopting households had more access to land and were more likely to receive information related to crop production and marketing.

A probit model was used to estimate the probability of adopting new technologies, with the dependent variable the use of hybrid or improved seeds, and explanatory variables: sex and age of household head, marital status, education, access to extension services and market information, land tenure, household size, income, land holdings, and number of hoes owned (a proxy for farm capital). Results of the adoption model are summarized in table 3. Estimated probit coefficients are not directly interpretable, and therefore marginal effects were calculated, representing the marginal change in the probability of adoption given a unit change in each independent variable.

The signs for most coefficients are consistent with expectations and theory. For example, a positive relationship is expected between adoption of new technologies and level of education, access to information, income, and asset ownership. The older the household head, the less likely he or she is to adopt a new technology.

Male-headed households are about 9 percent more likely to adopt hybrid or improved seed than female headed households. Households with junior high school as the highest education and those with secondary or higher are 8 and 9 percent more likely to adopt, respectively, than those with only primary education. An increase in the age of the household head by 1 year results in a decline in the probability of adoption of 0.13 percent. An increase in per capita income results in a significant but small increase in probability of adoption.

Impacts of Adoption of the Improved Peanut Variety on Aggregate Poverty

The probit parameter estimates are used to create a household-specific index of likelihood of adoption of new technologies, and peanut-producing households are ordered according to this index. We simulate three different adoption levels—15, 30 and 50 percent. Income changes implied by adoption of the new technology are applied to the first 15, 30, and 50 percent of the peanut-producing sample according to each individual household's adoption probability. This simulation ignores time dynamics associated with adoption; as noted above, our interviews with agents and scientists indicated that the 50 percent level of adoption would only be achieved after many years. As adoption grows over time from 15 to 50 percent, the distribution of income gains and losses changes among producers and consumers. Early-adopting producers will gain at low levels of adoption, while non-adopters will see their prices fall. The surplus captured by the 15 percent of adopters may be reinvested in productive capital that might lead to higher incomes (and less likelihood of poverty) in future years. Our simulation ignores this outcome.

Open-Economy Case

In the open-economy case, all income gains accrue to adopting producers through their changes in producer surplus. Using equation 3 and the K-shift from the surplus analysis, the change in income for adopting households can be approximated as:

(4) $d\,\pi_i(\tau) = K*P*Q_i*(1+0.5*K*\varepsilon) = 0.371*P*Q_i*(1+0.5*0.371) = 0.44*P*Q_i$,

or a 44 percent increase over the base value of peanut production. Post-adoption household income for adopters is $y_i{*}=y_i^0 + d\,\pi_i(\tau)$, where y_i^0 is initial (total household) income. This post-adoption income for adopters is compared to the poverty line[5] and the change in the FGT poverty index resulting from technology adoption is computed.

As the assumed adoption rate increases, more low-income producers fall into the category of adopting households, pulling down the mean household income of adopters (table 4). However, adoption of the Rosette-resistant peanut varieties leads to a modest increase (5 to 6 percent) in household income. This modest impact occurs because among peanut-producing households, peanut income is about 20 percent of total income.

In the closed-economy case, the income gains to adopting households (producer plus consumer surplus) range from 2.3 to 2.5% of pre-adoption income, depending on the assumed rate of adoption (table 4). Non-adopting producers see minor drops in total income (the loss in producer surplus is not quite offset by gains in consumer surplus). Non-producing consumers of peanuts also gain from lower prices; at the 50% level of adoption, the price decline is associated with a 1.7% rise in total annual income.

All three poverty indices fall modestly as a result of technology adoption (table 5). If all peanut producers in the region were to adopt the new varieties, under our assumptions about yield and cost changes, the poverty headcount among adopting households would fall about 4 percent in the open economy case. In the closed economy case, because the income gains are spread over many producers and consumers, the decline in poverty resulting from adoption is negligible.

The poverty gap and severity indices also fall following spread of the new peanut variety. In the case of the open-economy model, the poverty severity index falls by 2 percent with 100% adoption (from .1896 to .1716), representing a 10.5 percent decline in poverty severity. Since the poverty gap and severity indices fall as adoption increases, a number of households move closer to the poverty line and there is less inequality among poor households. Both these factors further highlight the poverty-reduction benefits of the new Rosette-resistant peanut seed.

The different assumptions about adoption rates have subtle effects on the distribution of household income. These differences are illustrated in figure 3, which shows the base density of income for peanut farmers in the open-economy case subtracted from the density of income at different levels of adoption (a negative density difference implies that the post-shift distribution has relatively fewer households in that range). At the 15 percent level of adoption, the post-adoption income distribution is shifted slightly to the right of the actual (pre-adoption) distribution, but the shift occurs very close to the $0.75 per day poverty line (the left-hand vertical line) and to its right. Few households at the very low end (left-hand tail) of the income distribution see their incomes grow as a result of adoption. At higher rates of adoption, the increase in income at very low levels of income becomes more pronounced. Higher adoption rates imply bigger rightward density shifts and more income increases for low-income farmers.

Our analysis of household-specific adoption rates hints that there will be a difference in the aggregate surplus change derived from the household analysis and that predicted by the usual market model. The reason for this discrepancy is that the market model assumes that adoption is independent of income and farm size. The aggregate surplus change at the 15 percent adoption rate assumes that 15 percent of the total base quantity of output is subject to the yield increase, while the household analysis shows that the first 15 percent of adopters are likely to be wealthier and have more land available than others; thus 15 percent adoption is likely to be associated with more than 15 percent of the base quantity.

While the impact on aggregate poverty reduction is rather modest, the analysis examines a single agricultural technology and does not account for dynamic effects, such as increased acreage devoted to peanuts and labor market effects. The impact of the new Rosette-resistant variety on demand for labor is likely to be minimal and, given a situation with high levels of seasonal underemployment, the labor market effects will be small at best. Over time, modest increases in incomes may lead to increased investments in household assets, leading to poverty-reducing growth effects.

Finally, additional sensitivity analysis was conducted around the key parameter of the per unit cost reduction due to either a different change in yield or input cost as a result of the new variety. For example, the projected increased cost of inputs as a result of adopting the new technology was fairly high at 50 percent. We reduced that increase to 25 percent and recalculated economic surpluses, net present values, and poverty rates. Details are available from the authors, but basically, the NPVs of benefits for the open economy case increased to $62.0 million and $51.3 million at 3 and 5 percent discount rates and for the closed economy case to $58.3 million and $48.2 million, increases of 42-44 percent. Poverty rates declined about 5 percent (.7084 to .6548) for the headcount index for peanut producers in the open economy case, and a half percent (.7084 to .7025) in the closed economy case. The severity index declined from .1896 to .1642 in the open economy case and from .1896 to .1833 in the closed economy case.

Conclusion

Results indicate that sizable research benefits are generated by adopting Rosette-resistant varieties. When we assume an open economy, these benefits accrue to adopting farmers, and are estimated to be from $US35.6 to $62.0 million over 15 years. The poverty indices show modest reductions in poverty, reflecting the fact that these surplus changes are distributed among a large number of peanut-producing households, many of whom are not poor. As assumed adoption rates increase, more poverty is reduced, because the poor are, in general less likely to adopt new technologies than the non poor. The depth and severity indices also fall with adoption, indicating that more households are drawn closer to the poverty lines (and hence escaping poverty) as a result of adoption.

In the closed-economy cases, price declines due to research-induced supply shifts lead to lower aggregate benefits of research ($US34.0 to $58.3 million). As these benefits are spread over more people (both producers and consumers), benefits per household decline and poverty reduction is small. This example indicates the importance of understanding a country's market conditions when estimating research impacts.

The main contribution of this paper is in illustrating a simple but important point. We have presented a method of allocating economic surplus changes to individual households; the method can be used to estimate other distributional impacts such as inequality, poverty impacts by sub-groups etc. The method can easily be adapted to other cases where policy makers wish to have ex ante information on agricultural research's impact on poverty reduction.

Footnotes

[1] Research leading to the Rosette-resistant varieties was supported by the Ugandan National Agricultural Research System, the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT) and the US Agency for International Development (USAID)-funded Peanut Collaborative Research Support Program (Peanut CRSP).

[2] Consumption of peanuts is 6 kg/person/year in Uganda, compared to 14 for all Sub-Sahara Africa according to FAO statistics.

[3] When $\alpha = 0$, P_α is the headcount index, or the proportion of the population that is poor. When $\alpha = 1$, P_α is the poverty gap index, a money-metric measure of depth of poverty. Depth is based on the aggregate poverty deficit of the poor relative to the poverty line. When $\alpha > 1$, P_α reflects increased sensitivity to inequality among the poor.

[4] Alternative models of adoption could be considered in our framework. For example, farmers may partially adopt the technology or, if the technology under consideration includes several components, adopt it sequentially (see Ersado, Amacher and Alwang 2004). The researcher would need to adapt the particular adoption model to compute the expected change in income/surplus at the household level.

[5] Due to lack of consensus about an income-measured poverty line in Uganda, we used a poverty line equal to $0.75 per person per day. Although this line is low by international standards (the World Bank standard is $1 per person per day), international standards tend to refer to consumption poverty and measured consumption is usually significantly higher than income. The poverty line can be adjusted accordingly as consensus about an income poverty line is attained.

References

Alston, J.M., Norton, G.W., P.G. Pardey. 1995. *Science Under Scarcity: Principles and Practice for Agricultural Research Evaluation and Priority Setting.* Ithaca, NY: Cornell University Press.

Alwang, J. and P.B. Siegel. 2003. "Measuring the Impacts of Agricultural Research on Poverty Reduction." *Agricultural Economics* 29:1-14.

Byerlee, D. 2000. "Targeting Poverty Alleviation in Priority Setting for Agricultural Research." *Food Policy* 25:429-445.

Ersado, Lire, G. Amacher and J. Alwang. 2004. "Productivity and Land Enhancing Technologies in Northern Ethiopia: Health, Public Investments, and Sequential Adoption." *American Journal of Agricultural Economics* 86: 321-331.

Foster, J., Greer, J., and E. Thorbecke. 1984. "A Class of Decomposable Poverty Measures." *Econometrica* 52:761-766.

Gibbons, R.W. 1977. "Disease, Pests and Weeds in Tropical Crops: Groundnut Rosette Virus." In: J. Cranz, J Schutter, and W. Koch, (eds.) *Diseases of Tropical Crops*. Berlin: Verlag Paul Parey, pp. 19-21.

Godtland, E. M; Sadoulet, E.; De Janvry, A.; Murgai, R.; Ortiz, O. 2004. "The Impact of Farmer Field Schools on Knowledge and Productivity: a Study of Potato Farmers in the Peruvian Andes." *Economic Development and Cultural Change* 53:63-92

International Crop Research Institute for Semi-Arid Tropics (ICRISAT), 2005. "Management of Groundnut Rosette: Past, Present, and Future" http://www.icrisat.org/text/research/grep/homepage/grephomepage/archives/rosette.html .

Karanja, D.D., Renkow, M. and E. Crawford. 2003. "Welfare Effects of Maize Technologies in Marginal and High Potential Regions of Kenya," *Agricultural Economics* 29:331-41

Mills, B. F. 1997. "Ex-ante Agricultural Research Evaluation with Site Specific Technology Generation: The Case of Sorghum in Kenya." *Agricultural Economics* 16:125-138.

Morris, M.L. and P.W. Heisey. 2003. "Estimating the Benefits of Plant Breeding Research: Methodical Issues and Practical Challenges." *Agricultural Economics* 29:241-252.

Moyo, S. 2004. "The Economic Impact of Peanut Research on the Poor: The Case of Resistance Strategies to Control Peanut Viruses in Uganda," M.S. thesis, Virginia Tech, Blacksburg.

Mutangadura G. and G.W. Norton. 1999. "Agricultural Research Priority Setting Under Multiple Objectives: An Example From Zimbabwe." *Agricultural Economics* 20:277-286.

Ravallion, M. 1992. *Poverty Comparisons: A Guide to Concepts and Methods*. LSMS Working Paper No. 88., The World Bank: Washington, DC.

Renkow, Mitch. 1993. "Differential Technology Adoption and Income Distribution in Pakistan: Implications for Research Resource Allocation," *American Journal of Agricultural Economics* 75:33-43.

Smith, V.H. and P.G. Pardey. 1997. "Sizing Up Social Science Research." *American Journal of Agricultural Economics* 79:1530-1534.

Thirtle, C., Lin L. and J. Piesse. 2003. "Impact of Research Led Agricultural Productivity Growth on Poverty Reduction in Africa, Asia and Latin America." *World Development*, 31:1959-1975.

Uganda National Household Survey 1999-2000. 2001. Uganda Bureau of Statistics, Ministry of Finance, Planning, and Economic Development, Kampala.

World Bank. 2006. Uganda Country Brief, (http://www.worldbank.org/ug/ctry_brief.htm).

Table 1. Base Poverty Indices for Peanut-Producing and All Households

Poverty Index	Peanut Producers (PP)	All sample (AS)
Headcount	0.7084	0.7456
Depth	0.3286	0.3894
Severity	0.1896	0.2454

Source: own computation using Uganda National Household Survey 1999-2000 (2001).

Table 2. Characteristics of Adopting and non-Adopting Households

Variable Description	Adopters (N=499)		Non-adopters (N=1560)	
	Mean	SD	Mean	SD
Age of household head (years)	43.2	15.5	45.3	16.6
Number of people normally residing in the household	6.4	3.7	5.5	3.3
Income per capita (US $)	165.0	163.0	127.0	160.0
Land owned per capita (Hectares)	2.9	4.4	2.9	3.9
Number of hoes owned	4.0	2.7	3.1	2.1
Extension advice (=1 indicates household received extension advice in 1998)	0.6	1.4	0.2	0.8
	N	**%**	**N**	**%**
Male household head	87	17.4	1144	73.3
Married household head	82	16.4	1142	73
Highest level of education completed				
-Primary	261	52.3	844	54.1
-Junior	20	4.0	43	2.8
- Secondary and beyond	135	27.05	224	14.36
Land tenure				
-Freehold	302	60.5	738	47.3
-Customary	160	32.0	745	47.8
Market info. received in 1998	222	44.5	498	32

Source: Uganda National Household Survey 1999-2000 (2001). Exchange rate $1:UGS1900

Table 3. Summary of the Probit Results: (Dependent Variable = 1 for Adopters and 0 Otherwise)

Parameter	Estimate	Marginal Effect	Standard Error	P-Value
Intercept	-2.9177		0.4291	<0.0001
Male-headed household	0.3107	0.0873	0.0949	0.0011
Age of household head Squared	-0.0001	-0.0000	0.0000	0.0154
Married Household Head	-0.0908	-0.0277	0.1003	0.3653
Completed junior level education	0.2451	0.0796	0.1744	0.1600
Completed secondary level educ.	0.2864	0.0916	0.0821	0.0005
Received extension advice	0.1464	0.0440	0.0304	<0.0001
Market information received, 1998	0.1918	0.0588	0.0667	0.0040
Hectares of land owned	0.0306	0.0092	0.0333	0.3587
Freehold tenure status	0.2824	0.0845	0.0645	<0.0001
Household Size	0.0264	0.0079	0.0749	0.7249
Income	0.1217	0.0365	0.0330	0.0002
Number of hoes owned	0.2661	0.0799	0.0704	0.0002

Note: N = 2059; Max-rescaled R-Square = 0.1278; Log-likelihood = -1048.13. Marginal effect refers to the marginal measured effect of the variable on the probability of adoption. P-Value is a test that the coefficient, which is distributed Chi-Square, is zero.

Table 4. Annual Household Income Before and After (Predicted) Adoption of Improved Peanut Variety

	Percent of households assumed to be adopting		
	15 %	30 %	50 %
Mean household income (prior to adoption) of adopters	2,056	1,660	1,351
Mean household income (prior to adoption) of non-adopters	930	850	767
Change in household income (US$-% in parentheses) -Open economy case			
Adopters	100 (4.9)	93 (5.6)	84 (6.2)
Change in household income (US$-%in parentheses)-Closed economy case			
Adopters			
Change in producer surplus	41 (2.0)	26 (1.6)	13 (1.0)
Change in consumer surplus	8 (0.4)	13 (0.7)	21 (1.6)
Total income change	49 (2.4)	39 (2.3)	34 (2.5)
Non-adopters-after adoption			
Change in producer surplus	-5 (0.2)	-9 (0.5)	-15 (1.1)
Change in consumer surplus	5 (0.2)	9 (.05)	14 (1.1)
Total income change	0	0	-1
Non-producing consumers			
Total income change	4 (0.4)	8 (0.9)	13 (1.7)

Source: Own computation using Uganda National Household Survey 1999-2000 (2001) and results from table 3.

Note: The exchange rate between the US$ and the Ugandan Shilling was $1: UGX1900 in August 2003.

Table 5. Poverty Indices for Peanut-producing and All Sample Households at Various Adoption Rates

Adoption	0%	0%	15%		30%		50%		100%	
	Peanut Producers (PP)	All sample (AS)	P P	AS	PP	AS	PP	AS	PP	AS
Open Economy										
Headcount	0.7084	0.7456	0.7028	0.7442	0.6955	0.7424	0.6875	0.7404	0.6710	0.7363
Depth	0.3286	0.3894	0.3265	0.3888	0.3216	0.3876	0.3169	0.3864	0.3025	0.3828
Severity	0.1896	0.2454	0.1882	0.2451	0.1856	0.2444	0.1826	0.2437	0.1716	0.2409
Closed Economy										
Headcount	0.7084	0.7456	0.7059	0.7432	0.7079	0.7434	0.7048	0.7426	0.7071	0.7416
Depth	0.3286	0.3894	0.3284	0.3287	0.3272	0.3879	0.3261	0.3868	0.3244	0.3844
Severity	0.1896	0.2454	0.1893	0.2449	0.1886	0.2442	0.1878	0.2432	0.1858	0.2410

Source: Own computation using FGT formula and data from Uganda National Household Survey 1999-2000 (2001) and results from table 2.

Note: Headcount implies $\alpha = 0$ in FGT formula, Depth implies $\alpha = 1$, and Severity implies $\alpha = 2$.

Table 6. Income Changes from Aggregate Surplus Analysis Compared to Household- Level Changes (in $US)

Adoption Rate	15%	30%	50%	100%
Income change (economic surplus model)	1,835,000	3,768,000	6,501,000	14,105,000
Income change (household analysis)	3,173,000	5,874,000	8,218,000	14,466,000
Difference	-1,338,000	-2,106,000	-1,717,000	-361,000

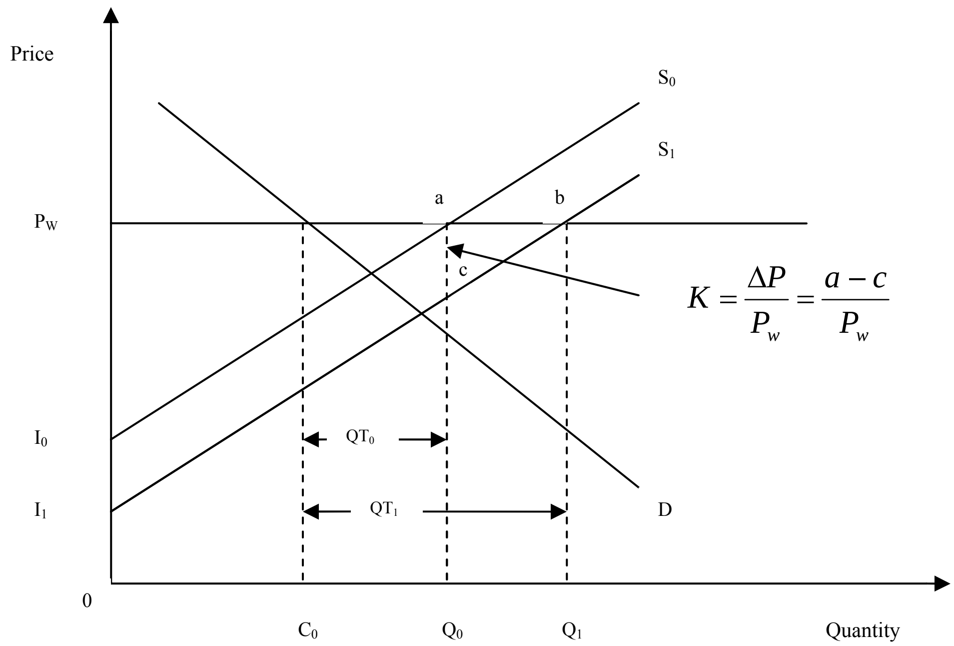


Figure 1. Research benefits in a small open economy

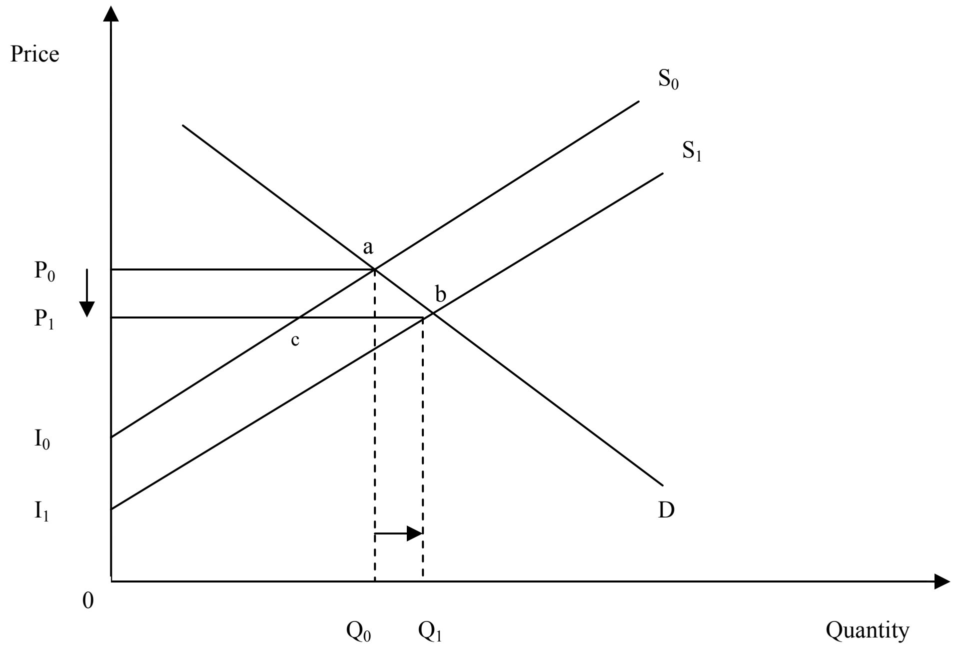
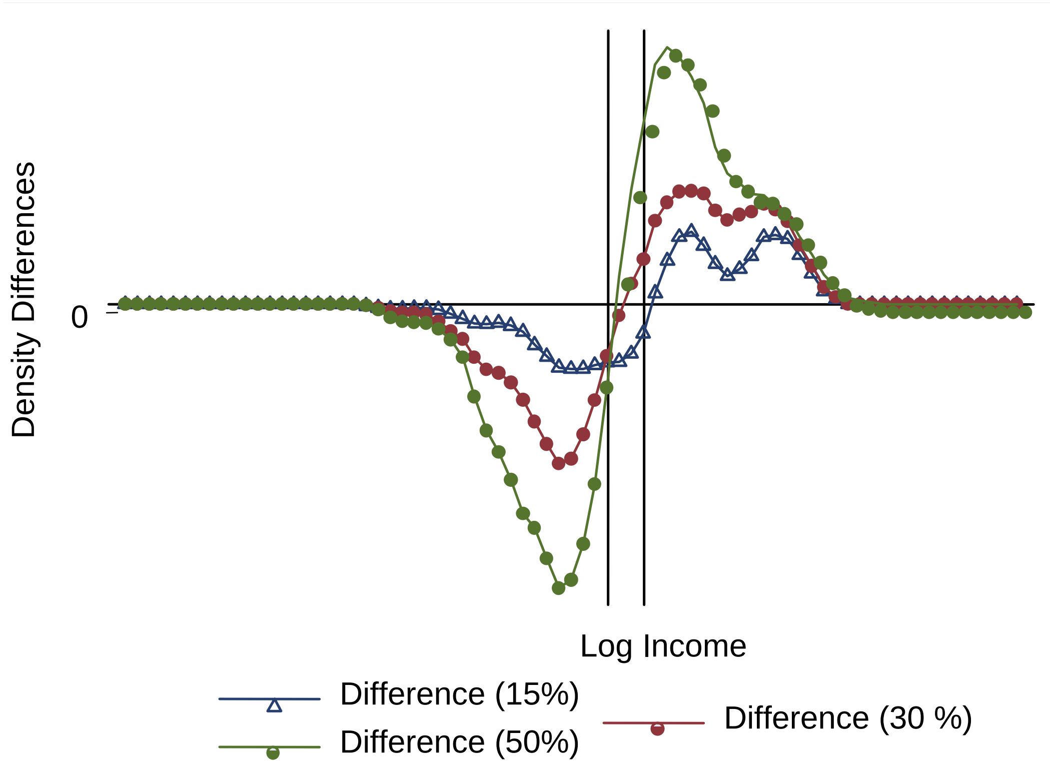


Figure 2. Research benefits in a small closed economy



Source: Own computation using Uganda National Household Survey 1999-2000

Figure 3. Income density differences, base density subtracted from densities following different levels of adoption