The efficiency–equity tradeoffs in agricultural research priority setting: the potential impacts of agricultural research on economic surplus and poverty reduction in Nigeria

Arega D. Alene[*]
International Institute of Tropical Agriculture (IITA), Ibadan, Nigeria

Victor M. Manyong
IITA–Dar es Salaam, Tanzania

Eric F. Tollens
Katholiet Universiteit Leuven, Leuven, Belgium

Steffen Abele
IITA–Kampala, Uganda

Contributed paper prepared for presentation at the International Association of Agricultural Economists Conference, Gold Coast, Australia, August 12-18, 2006

[*] Corresponding Author. IITA, c/o Lambourn & Co., Carolyn House, 26 Dingwall Road, Croydon CR9 3EE, UK. Tel: (234-2) 241-2626 Ext 2293 (Office), 2442 (Home), Fax: (234-2) 241-2221, Email: A.Alene@cgiar.org.

1. Introduction

Declining agricultural research budgets coupled with worsening poverty have increasingly required formal priority setting of public agricultural research in developing countries to ensure that scarce research resources are allocated in ways that will have the greatest impact on the poor (Byerlee, 2000). However, there is no consensus regarding whether the poor benefit more from agricultural research that pursues efficiency or equity objectives, and hence of whether research priorities should be set according to efficiency or equity criteria. It has long been recognized that while an agricultural research system is best at helping a country achieve its efficiency objective through increased productivity, it is a relatively weak instrument for changing income distribution in rural areas, and the cost to society could be high if the research portfolio is biased by pursuing non-efficiency goals (Ruttan, 1982; Alston et al., 1995; Otsuka, 2000). While most priority setting works have thus emphasized efficiency objectives (e.g., Mills, 1997; Nagy and Quddus, 1998; Mutangadura and Norton, 1999), donors and governments have now placed greater emphasis on poverty alleviation as the central objective of public agricultural research investments.

Clearly, there remains an important research gap relating to the nature and magnitude of the efficiency–equity tradeoffs. This means that neither efficiency nor equity can be easily justified as the basis for setting strategic agricultural research priorities. This paper estimates the potential impacts of agricultural research on economic surplus and poverty reduction in Nigeria, identifies strategic priorities according to both efficiency and equity criteria, and examines the nature and magnitude of the efficiency–equity tradeoffs. The

paper is organized as follows. The next section gives an overview of agricultural research in Nigeria. The third section presents the economic surplus method and data, whereas the fourth section presents the corresponding method and data for the poverty analysis. The results are presented in the fifth section and the last section draws conclusions and policy implications.

2. An overview of agricultural research in Nigeria

Agricultural research in Nigeria is principally carried out by eighteen national agricultural research institutes. Six of these deal with arable crops, four with forestry and tree crops, three with livestock, two with fisheries, and one each with extension, processing, and storage. Nigeria's agriculture also benefits from the international agricultural research carried out by the Nigeria-based International Institute of Tropical Agriculture (IITA). IITA has developed and released numerous improved varieties of cassava, yam, maize, cowpea, plantain and banana, and soybean. Nigeria's agricultural research has come under pressure to contribute to poverty reduction goals in the face of declining budgets. In 2000, for instance, although Nigeria employed the highest total number of full time equivalent researchers in SSA (11%), its share of spending was only 7% of the total US$1.5 billion (i.e., US$10.5 million) (Beintema and Stads, 2004). Nigeria represents the largest share of the overall economy and total population of West Africa and proper targeting of agricultural research investments would thus result in large pay-offs not only for Nigeria but also for the entire sub-region.

3. Economic surplus method and data

Economic surplus analysis is the most widely used means of ex ante evaluation of the impacts of agricultural research for priority setting (Alston et al., 1995). Typically, total net economic benefits of agricultural research arising from research-induced supply shifts are estimated based on a parallel downward shift in the (linear) supply curve of a commodity (e.g., Mills, 1997; Nagy and Quddus, 1998; Mutangadura and Norton, 1999). In this study, the markets for grains and roots and tubers were modeled as small, open economies, whereas the markets for fruits, vegetables, and livestock were represented by closed economies. Research benefits were estimated based on the economic surplus models and formulas presented in Alston et al. (1995). The change in total economic surplus was projected for a 20-year period from 2004 and the projected benefits and research costs over the 20-year period were discounted to derive the net present values (NPV). The model was estimated using the DREAM program (Wood et al., 2001).

Data relating to agricultural research and technologies, including yields, costs, research success, and adoption were obtained primarily from researchers, research managers, and extensionists through extensive discussions and interviews using a detailed set of questionnaires. A total of 144 scientists and research managers from IITA and more than ten national agricultural research institutes were involved in generating the research and technology data. Market-related data, including production, prices, and supply and demand elasticities were also collected from a variety of sources.

4. Poverty analysis method and data

With household-level data, income growth associated with crop-specific yield changes can be aggregated to create measures of changes in poverty and inequality. This study adapts Alwang and Siegel's (2003) model of income determination for small-scale agricultural producers to estimate the poverty impacts of alternative commodity research programs. With household-level data, income growth associated with commodity-specific yield changes can be aggregated to create measures of changes in poverty and inequality. Household income is defined as the sum of farm income (I), off-farm income, and monetary and in-kind transfers to a household. For the *i*th household, farm income can be defined as

$$\mathrm{I}_i = \mathrm{H}_i \mathrm{Y}_i \mathrm{P} - \mathrm{H}_i C_i$$

where H is a vector of hectares of land allocated to each of the crops or number of heads of livestock raised, Y a diagonal matrix of yields, P a vector of prices, and C is a vector of per-hectare or per animal costs of production. Changes in farm incomes can be decomposed as

$$\Delta\mathrm{I}_i = \Delta\mathrm{H}_i(\mathrm{Y}_i\mathrm{P} - C_i) + \mathrm{H}_i\Delta\mathrm{Y}_i\mathrm{P} + \mathrm{H}_i\mathrm{Y}_i\Delta\mathrm{P} - \mathrm{H}_i\Delta C_i$$

This shows the four major effects that commodity-specific research has on household income and poverty. From the four major effects of agricultural research on farm incomes, the effects through yields, prices, and cost changes are the most important. The expected change in farm incomes due to agricultural research is thus modeled as follows

$$E(\Delta\mathrm{I}_i) = \mathrm{H}_i\Delta\mathrm{Y}_i\,\mathrm{Pr}_i\,\mathrm{P} + \mathrm{H}_i\mathrm{Y}_i\Delta\mathrm{P} - \mathrm{H}_i\Delta C_i$$

where Pr_i is a diagonal matrix of probabilities of adoption of the agricultural technology for the *i*th household. A Probit model of adoption of purchased inputs was estimated to predict adoption probabilities. Because households either adopt or do not adopt a technology, the 25th percentile probability cutoff point (Alwang and Siegel, 2003) was used as an adoption threshold. Expected changes in farm incomes were added to initial household income and the resulting incomes were compared to a poverty line and aggregated to form expected changes in poverty and inequality measures.

Two types of data were needed for the household level poverty analysis: household survey data and forecasted changes in yields and production costs. Household survey data collected in 2001 and 2002 from a nationally representative sample of 3180 households were used to estimate the household level impacts of agricultural research (Kormawa et al., 2003).

5. Results

5.1. Efficiency measures and priorities

Table 1 presents commodity research program priorities based on the estimated economic benefits from the economic surplus analysis. The commodity research programs can be categorized into high, medium, and low priority groups. The top commodity program is yam, with a total NPV of US$7.5 billion and IRR of 131%. The high priority programs in order of decreasing importance are yam, cassava, maize, rice, cowpea, citrus fruits, sorghum, plantain, poultry, millet, and groundnut. Generally, leafy vegetables, fruits, and

livestock are medium priority programs, whereas other vegetables and industrial crops are low priority programs.

Table 1 here

5.2. Equity measures and priorities

Disaggregated household income data were used to set a relative poverty line following World Bank (1996) where two-third of the mean per capita income was used as the poverty line for Nigeria. The results show that about 58.6% of rural Nigerians are poor. Federal Office of Statistics Nigeria (FOS, 2004) also reports a poverty incidence of 57.8% for all Nigeria. The Gini coefficient of income inequality is 0.572.

Table 2 presents commodity research program priorities based on poverty reduction following a 50% increase in agricultural research budgets. Maize research has the biggest potential impact on poverty reduction where poverty incidence would be reduced by 5% following increased maize research. The high priority commodity programs in order of decreasing importance are maize, cowpea, rice, yam, cassava, millet, sorghum, groundnut, and poultry. Potential impacts of most research programs on income inequality are negligible. While most poverty-reducing commodity programs also have inequality-reducing impacts, some can actually increase inequality. Maize research has the highest inequality-reducing impact, indicating that it is grown by most of the poor including the poorest of the poor. Cocoa research has a negligible effect on poverty but

increases income inequality, indicating that much of the producer benefits from this research program will be captured by the better-off farmers.

Table 2 here

5.3. Efficiency–equity priorities and tradeoffs

An important research question relating to the efficiency–equity tradeoffs in public agricultural research has been the issue of whether the poor benefit more from programs that pursue efficiency or equity objectives. The argument for efficiency in public agricultural research is that programs that maximize benefits to society are those that also maximize benefits to the poor. Diverting resources away from current allocations to programs that pursue equity objectives will involve substantial losses of benefits to society, including the poor. In this paper, the efficiency–equity tradeoffs are examined using rank correlation and graphical analyses of research priorities established according to efficiency and equity criteria. First, the correlations of the priorities according to the efficiency and the equity criteria were examined using the Spearman's rank correlation coefficient (ρ). Differences in ranking of research programs are a measure of the tradeoffs between the efficiency and equity criteria. However, the nature of the tradeoffs across the full range of the research programs cannot be revealed only through rank correlations. Therefore, projected benefits to society and projected benefits to poor households were compared based on research program portfolios established according to the efficiency and equity criteria.

The measure of benefits to poor households was preferred to the poverty reduction measure to represent equity, because the analysis of tradeoffs requires a common unit of measurement for efficiency and equity. That is, the total benefits to society and the proportion of households lifted out of poverty following increased research are not directly comparable. Aggregate benefits to the poor were estimated as the total economic surplus that would be captured by the poor (NPV^p) depending on their share in total production of each tradable commodity and their share in both production and consumption of each non-tradable commodity (Byerlee, 2000). The appropriateness of this measure to be used as a measure of equity was tested using Spearman's rank correlation. Tables 3 and 4 present, respectively, the research priorities and the rank correlations among commodities prioritized according to the three criteria: efficiency, poverty reduction-based equity, and equity based on aggregate benefits to the poor. The correlation analysis revealed over 90% Spearman rank order correlation of commodity priorities according to aggregate benefits to the poor with commodity priorities according to the efficiency and the poverty reduction-based equity criteria, indicating little or no significant trade-offs.

Table 3 here

Table 4 here

A proper analysis of the magnitude of the efficiency–equity tradeoffs should go beyond rank correlations. Fig. 1 illustrates the costs to society in terms of forgone benefits, measured as the shortfall of benefits to all households following the allocation of research

resources in ways that maximize benefits to the poor as opposed to maximizing benefits to all households. It is shown that societal benefits from pursuing efficiency and equity objectives converge and this convergence is more or less sustained after the top five commodity programs have been included in the research portfolio. The overall effect of prioritizing on the basis of equity on societal benefits is only 3%, relative to the societal benefits from efficiency-based priorities. That is, society would forego only 3% of total research benefits if agricultural research programs were prioritized on the basis of equity. However, analysis of forgone benefits to society alone does not reveal all that is of interest regarding the efficiency–equity tradeoffs. It is also important to know the marginal benefits to the poor from prioritizing research programs according to the equity criterion (i.e., benefits to the poor). Fig. 2 illustrates how the total benefits to the poor from the equity-based research portfolio compare with the efficiency-based portfolio. The benefits to the poor from the equity-based research portfolio are consistently higher than the efficiency-based portfolio. The analysis indicates that the poor would capture 24% of total research benefits, compared to their share of total production of 29%. The overall effect of prioritizing on the basis of equity on research benefits to the poor is 8%, which is equivalent to US$155 million. That is, the poor would capture 8% more research benefits from equity-based research resource allocations than they would from efficiency-based allocations. The relative importance of the marginal benefits to the poor from equity-based priorities and the lack of significant efficiency–equity tradeoffs indicate possibilities to direct research benefits to the poor without compromising research efficiency.

Figures 1 and 2 here

6. Conclusions and policy implications

The results of this study show that although introducing a poverty dimension into priority setting does not result in a significant shift in strategic priorities, there are opportunities for sharpening the focus of agricultural research on poverty alleviation. There are no significant efficiency-equity tradeoffs because the rural poor in Nigeria depend mainly on the production of food staples both for consumption and household incomes. Neither the forgone benefits to society nor the marginal benefits to the poor are significant from prioritizing research according to equity, but the marginal benefits to the poor are relatively more important. The relative importance of the marginal benefits to the poor from equity-based priorities and the lack of significant efficiency-equity tradeoffs indicate that opportunities exist to direct research benefits to the poor without compromising overall benefits to society. Such opportunities are likely to be greater in SSA where the direct impacts of research on poor producers have been shown to be more important than the indirect effects associated with lower consumer prices and employment. The direct impacts on producers are also likely to dominate research benefits in other regions in the wake of growing trade liberalization and changes in product demands with rising incomes and increasing population.

However, efforts towards the realization of the potential research benefits to the poor from pursuing either efficiency or equity objectives would be more important than efforts to increase the marginal benefits to the poor from targeting poverty alleviation. The results show that substantial benefits to the poor are possible from programs pursuing

either efficiency or equity objectives, provided that there would be widely-shared adoption of the products of the research system. However, empirical evidence from the Green Revolution has shown that agricultural research has had negative direct impacts on the poor producers, mainly because of their low adoption of agricultural technologies. This has again been due to poor access to irrigation, credit, extension services, and input supply. Differential adoption of technologies by the poor and the better-off producers means that technology-induced price decreases for non-tradable food commodities will cause welfare losses to the poor. If poor food producers do not adopt technologies, the benefits of technological change will simply bypass them and they will face lower prices for their products. Targeting research is thus a necessary but not a sufficient condition for poverty alleviation. For potential benefits to the poor to be realized, the poor should simultaneously have improved access to credit, extension, and input supply. Therefore, both agricultural research and support services, including extension, credit, input supply, and infrastructure should be targeted to the poor to achieve poverty alleviation through agricultural research.

References

Alston, J.M., Norton, G.W., Pardey, P.G., 1995. Science under Scarcity: Principles and Practice for Agricultural Evaluation and Priority Setting. Cornell University Press, New York, USA.

Alwang, J., Siegel, P.B., 2003. Measuring the impacts of agricultural research on poverty reduction. Agric. Econ. 29, 1–14.

Beintema, N.M., Stads, G-J., 2004. Investing in sub-Saharan African Agricultural Research: Recent Trends. Vision 2020 Africa Conference Brief 8, IFPRI, Washington, D.C., USA.

FOS (Federal Office of Statistics Nigeria), 2004. Nigeria Living Standards Survey, 2003/04. Federal Office of Statistics, Abuja, Nigeria.

Kormawa, P.M., Legg, C., Okechukwu, R., Alabi, R., 2003. Rural livelihood poverty mapping: contribution to R4D priority setting. 2003 Work Planning Week Abstracts, International Institute of Tropical Agriculture (IITA), Ibadan, Nigeria.

Mutangadura, G., Norton, G.W., 1999. Agricultural research priority setting under multiple objectives: an example from Zimbabwe. Agric. Econ. 20(3), 277–292.

Nagy, J.G., Quddus, M.A., 1998. National agricultural commodity research priorities for Pakistan. Agric. Econ. 19, 327–340.

Otsuka, K., 2000. Role of agricultural research in poverty reduction: lessons from the Asian experience. Food Policy 25(4), 447–462.

Ruttan, V.W., 1982. Agricultural Research Policy. University of Minnesota Press, Minneapolis, USA.

Wood, S., You, L., Baitx, W., 2001. Dynamic Research Evaluation for Management (DREAM) User Manual. International Food Policy Research Institute (IFPRI), Washington, D.C., USA.

World Bank, 1996. Nigeria—Poverty in the midst of plenty: the challenge of growth with inclusion. A Poverty Assessment Report, World Bank, Washington, D.C., USA.

Table 1

Agricultural research priorities in Nigeria based on economic surplus following a 50% increase in agricultural research budgets

Commodity	NPV (US$ million)	IRR (%)	Rank
Yam	7524	131	1
Cassava	6665	127	2
Maize	3460	118	3
Rice	2463	115	4
Cowpea	2141	110	5
Citrus	973	73	6
Sorghum	957	90	7
Plantain	931	84	8
Poultry	828	87	9
Millet	737	84	10
Groundnut	494	75	11
Beef	351	49	12
Goat	278	59	13
Oil palm	258	53	14
Leafy vegetables	248	69	15
Pineapple	219	51	16
Mango	218	51	17
Pig	216	47	18
Sheep	195	53	19
Sweet potato	153	53	20
Pepper	140	58	21
Soybean	120	56	22
Melon	73	48	23
Cocoa	67	37	24
Dairy	46	26	25
Cashew nut	44	41	26
Onion	44	40	26
Tomato	43	40	27
Cotton	28	35	28
Sesame	13	27	29
Natural rubber	11	21	30
Ginger	9	24	31
Irish potato	8	19	32
Wheat	5	19	33
Sugarcane	4	15	34

Table 2

Agricultural research priorities in Nigeria based on poverty reduction following a 50% increase in agricultural research budgets

Commodity	Poverty reduction (%)	Change in inequality (Gini)	Rank
Maize	5.00	−0.018	1
Cowpea	3.80	−0.008	2
Rice	3.70	0.008	3
Yam	3.60	0.061	4
Cassava	3.57	0.072	5
Millet	2.20	−0.004	6
Sorghum	1.80	−0.005	7
Groundnut	1.50	−0.006	8
Poultry	1.30	−0.006	9
Melon	1.10	0.008	10
Beef	0.90	−0.002	11
Dairy	0.90	−0.002	11
Sheep	0.90	−0.004	11
Goat	0.90	−0.005	11
Cocoa	0.40	0.034	12
Soybean	0.10	−0.001	13
Wheat	0.00	0.000	14
Plantain	0.00	0.000	14
Sesame	0.00	0.000	14
Leafy vegetables	0.00	0.000	14
Onions	0.00	0.000	14
Pepper	0.00	0.000	14
Ginger	0.00	0.000	14
Tomato	0.00	0.000	14
Sweet Potato	0.00	0.000	14
Irish Potato	0.00	0.000	14
Sugarcane	0.00	0.000	14
Natural rubber	0.00	0.000	14
Oil palm	0.00	0.000	14
Cotton	0.00	0.000	14
Cashew nut	0.00	0.000	14
Citrus fruit	0.00	0.000	14
Pineapple	0.00	0.000	14
Mango	0.00	0.000	14
Pig	0.00	0.000	14

Table 3

Comparison of research program priorities in Nigeria using efficiency and equity criteria

Efficiency		Equity (poverty reduction)		Equity (Benefits to the poor)	
Priorities	NPV (US$ million)	Priorities	(%)	Priorities	NPV^p (US$ million)
Yam	7524	Maize	5.00	Maize	1626
Cassava	6665	Cowpea	3.80	Cowpea	921
Maize	3460	Rice	3.70	Rice	714
Rice	2463	Yam	3.60	Yam	677
Cowpea	2141	Cassava	3.57	Cassava	667
Citrus	973	Millet	2.20	Poultry	464
Sorghum	957	Sorghum	1.80	Sorghum	344
Plantain	931	Groundnut	1.50	Millet	265
Poultry	828	Poultry	1.30	Groundnut	242
Millet	737	Melon	1.10	Plantain	233
Groundnut	494	Beef	0.90	Beef	221
Beef	351	Dairy	0.90	Goats	161
Goat	278	Sheep	0.90	Sheep	123
Oil palm	258	Goat	0.90	Citrus	97
Leafy vegetables	248	Cocoa	0.40	Soybean	86
Pineapple	219	Soybean	0.10	Leafy vegetables	74
Mango	218	Wheat	0.00	Sweet potato	38
Pig	216	Plantain	0.00	Dairy	29
Sheep	195	Sesame	0.00	Oil palm	26
Sweet potatoes	153	Leafy vegetables	0.00	Pineapple	22
Pepper	140	Onion	0.00	Mango	22
Soybean	120	Pepper	0.00	Pig	22
Melon	73	Ginger	0.00	Pepper	20
Cocoa	67	Tomato	0.00	Tomato	13
Dairy	46	Sweet potato	0.00	Onion	10
Cashew nut	44	Irish potato	0.00	Melon	7
Onion	44	Sugarcane	0.00	Sesame	7
Tomato	43	Natural rubber	0.00	Cocoa	5
Cotton	28	Oil palm	0.00	Cashew nut	4
Sesame	13	Cotton	0.00	Ginger	3
Natural rubber	11	Cashew nut	0.00	Cotton	3
Ginger	9	Citrus fruit	0.00	Irish potato	2
Irish potato	8	Pineapple	0.00	Natural rubber	1
Wheat	5	Mango	0.00	Wheat	1
Sugarcane	4	Pig	0.00	Sugarcane	0.4

Table 4
Rank correlations among commodities prioritized according to efficiency, poverty reduction, and aggregate benefits to the poor in Nigeria

	Efficiency (NPV)	Equity (Poverty reduction)	Equity (NPV^p)
Efficiency (NPV)	1.00	0.75	0.94
Equity [a] (Poverty reduction)	0.75	1.00	0.92
Equity (NPV^p)	0.94	0.92	1.00

[a] Rank correlations between the poverty reduction-based rankings and the efficiency and NPV^p rankings are only for the 10 priority commodities effectively ranked using the poverty reduction criterion.

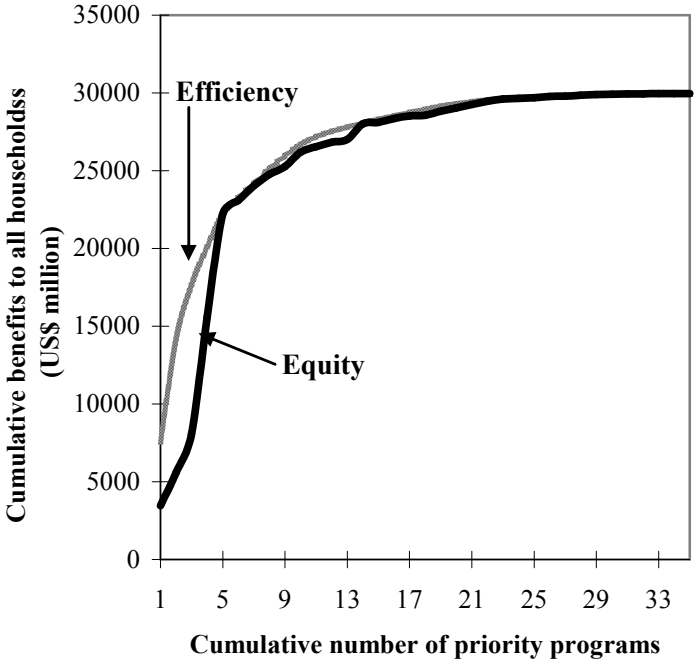

Fig. 1. Cumulative benefits to all households from adding research programs according to efficiency and equity criteria.

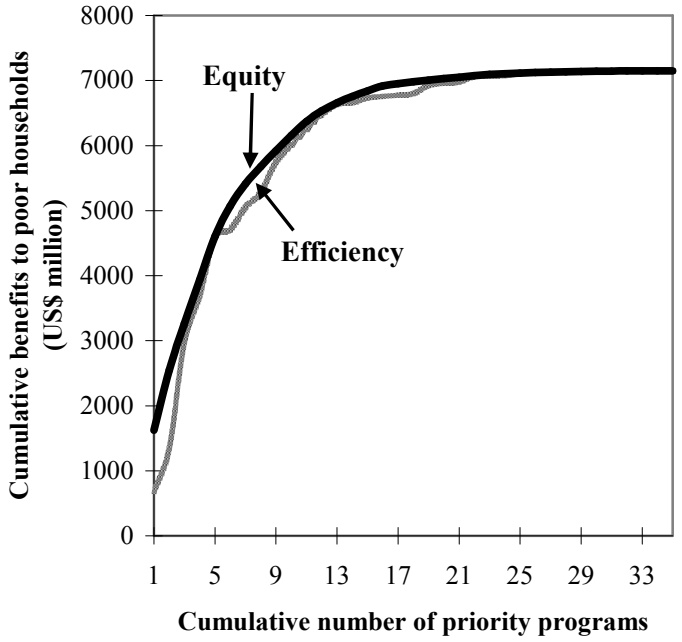

Fig. 2. Cumulative benefits to poor households from adding research programs according to efficiency and equity criteria.