AGRICULTURAL ECONOMICS

Agricultural Economics 40 (2009) 1–14

Efficiency–equity tradeoffs and the scope for resource reallocation in agricultural research: evidence from Nigeria

Arega D. Alene[a,*], V. M. Manyong[b], Eric F. Tollens[c], Steffen Abele[b]

[a]*International Institute of Tropical Agriculture (IITA), P.O. Box 30258, Lilongwe, Malawi*
[b]*International Institute of Tropical Agriculture (IITA), P.O. Box 6226, Dar es Salaam, Tanzania*
[c]*Katholieke Universiteit Leuven, W. de Croylaan 42, 3001 Leuven, Belgium*

Received 14 June 2007; received in revised form 21 June 2008; accepted 13 August 2008

Abstract

On the basis of projected economic and poverty impacts of alternative commodity research programs, this article assessed efficiency and equity tradeoffs and the scope for research resource reallocation in Nigeria. Given the importance of major food staples to both poor and nonpoor households in production and consumption, introducing a poverty dimension revealed no significant shift in priorities compared with those implied by efficiency. The results showed that neither the additional benefits to the poor nor the foregone benefits to society are significant from prioritizing research according to equity—relative to efficiency—criteria. As current priorities are supported by neither efficiency nor equity criteria, however, there is considerable scope for maximizing research benefits to the poor through informed reallocation of research resources. The article concludes with a discussion of the patterns of resource reallocations implied by efficiency and equity criteria.

JEL classification: I32, I38, O13, O32, Q16

Keywords: Economic surplus; Poverty reduction; Priority setting; Nigeria; Africa

1. Introduction

Agricultural research managers and policy makers have come under increasing pressure to do more with less agricultural research budgets. In this situation, agricultural research priority setting has become increasingly important for allocating scare research resources among competing needs to achieve greater impacts. Efficiency objectives aimed at maximizing economic surplus have been central to public agricultural research policy. As a result, agricultural research priority setting efforts have considered economic efficiency objectives and prioritized research programs according to the net present value (NPV) of projected research benefits (e.g., Kelley et al., 1995; Mills, 1997; Nagy and Quddus, 1998). However, declining agricultural research budgets in the face of worsening poverty have increasingly required targeting agricultural research to achieve greater impacts on the poor.

This has motivated efforts to set research priorities according to potential impacts on poverty reduction. A few studies have incorporated equity considerations using criteria such as the number of poor people in a region rather than the benefits that would actually accrue to the poor (e.g., Kelley et al., 1995; von Oppen and Ryan, 1985). In assessing broader regional research priorities for the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT), von Oppen and Ryan (1985) used the number of poor people in a region as a variable representing equity. Kelley et al. (1995) also used the number of poor people and the extent of female illiteracy in assessing thematic research priorities for ICRISAT. For a number of reasons, however, not all poor households in a region or in areas where particular research activities are conducted would benefit from agricultural research. Mutangadura and Norton (1999) assessed priorities using efficiency and equity criteria, with equity measured as the potential benefits to small-scale farmers, relative to commercial farmers. As not all small-scale farmers are poor, benefits to small-scale farmers may not adequately represent poverty alleviation objectives. Recently, an explicit poverty dimension has been introduced in agricultural research

*Corresponding author. Tel.: +265-1-707014/022; fax: +265-1-707026. *E-mail address:* A.Alene@cgiar.org (A. D. Alene).

Data Appendix Available Online

A data appendix to replicate main results is available in the online version of this article. Please note: Wiley-Blackwell, Inc. is not responsible for the content or functionality of any supporting information supplied by the authors. Any queries (other than missing material) should be directed to the corresponding author for the article.

DOI: 10.1111/j.1574-0862.2008.00340.x

priority setting (e.g., Alene et al., 2007; Alwang and Siegel, 2003; Byerlee, 2000). Alene et al. (2007) assessed strategic research priorities for three agro-ecological zones in Nigeria based on potential impacts of alternative commodity programs on poverty reduction.

However, little is known about whether poverty considerations would indeed result in a significant shift in research priorities, relative to those based on efficiency. Whether greater research benefits would actually accrue to the poor by pursuing equity rather than efficiency objectives in priority setting is an empirical question. It is argued 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 nonefficiency goals (Alston et al., 1995; Otsuka, 2000; Ruttan, 1982). Clearly, there is need for empirical evidence on whether a poverty-based approach would result in a shift in priorities leading to greater benefits to the poor, relative to efficiency-based priorities. Similarly, there is little evidence on the scope for resource reallocation in terms of the extent to which actual priorities and resource allocations deviate from optimal priorities. The objective of this article is thus to assess the efficiency and equity tradeoffs and the scope for resource reallocation in agricultural research in Nigeria. Specifically, the article evaluates the possibility for greater equity gains from equity-based priority setting as well as the opportunities for maximizing research benefits through resource reallocation. The next section gives an overview of agricultural research in Nigeria, whereas the third and fourth sections present the methods and data, respectively. The results are presented in the fifth section and the last section draws conclusions.

2. Overview of agricultural research in Nigeria

2.1. Organization of agricultural research

Agricultural research in Nigeria is carried out by national agricultural research institutes and higher education agencies, in partnership with international agricultural research centers. Research is conducted on a wide range of commodities: arable crops, forestry and tree crops, livestock, fisheries, extension, and processing and storage. There are over 80 government research institutes and higher-education agencies engaged in agricultural research (Beintema and Ayoola, 2004). Nearly two-thirds of Nigeria's research capacity rests with the government agencies, most of which fall under the responsibility of the Agricultural Sciences Department within the Federal Ministry of Agriculture and Rural Development. The Department is responsible for the coordination, planning, and evaluation of the activities of the research institutes.

2.2. Agricultural research expenditures

Total agricultural research and development (R&D) spending exhibited a negative average growth rate of 2% per year between the 1970s and mid 1990s. After a few years of growth in the early 1970s, total spending dropped by two-thirds from an average of about $130 million in 1993 international dollars in the mid 1970s to less than $50 million in the mid 1990s. Following a recent increase in salary levels and an increase in government contributions to agricultural research, total spending has increased in recent years (Beintema and Ayoola, 2004).

In 2000, for example, the country's agricultural research system employed over 1,352 full-time equivalent (FTE) researchers and spent 3.6 billion 1999 Naira on R&D, which is equivalent to $106 million in 1993 international prices (Beintema and Ayoola, 2004). This represented the highest total number of FTE researchers in SSA (11%), although Nigeria's share of spending was only 7% of the total $1.5 billion in 1993 international dollars, indicating that the resources available per Nigerian researcher were more limited (Beintema and Stads, 2004). A decline in total spending relative to total FTE researchers resulted in a decline in spending per scientist almost by half, from $171,000 in 1971 to $78,000 in 2000 (1993 international dollars), although the 2000 figure was still twice the level of spending per scientist in the mid 1990s (Beintema and Ayoola, 2004).

3. Methods

Identifying the unit of analysis is an important step in assessing agricultural research priorities. In this regard, commodity-based priority setting reflects the dominant paradigm for organizing agricultural research. Most rate of return studies of technological success refer to commodity innovations. Commodity level research priority assessment provides the potential to strategically guide resource allocation in ways that will generate the greatest benefits. Byerlee (2000) argues that the greatest strategic leverage in priority setting is provided by national level resource allocations across major research programs and institutes. This article assesses strategic priorities at commodity level, with a focus on the nature and magnitude of the efficiency and equity tradeoffs.

3.1. Economic congruence analysis

A variety of approaches and methods have been used to generate information for priority setting in agricultural research, but there is no best approach for all contexts. Because agricultural research is critical for economic growth, examining the economic importance of commodities is a good starting point for the initial evaluation of research resource allocation. In other words, this starting point evaluates the congruence or parity of value of production and research expenditures across commodities. Economic congruence generally implies that the importance of a commodity in agricultural research should be proportional to the importance of the commodity in the national economy.

Congruence is defined as

$$\frac{E_i}{\sum_{i=1}^{n} E_i} = \frac{P_i Q_i}{\sum_{i=1}^{n} P_i Q_i} = S_i \quad (1)$$

where E_i is the research expenditure on the ith commodity, $P_i Q_i$ is the value of production of the ith commodity as the product of price and quantity, and S_i is the proportion or share of the ith commodity in agricultural production. In practice, scientist years are often used as a proxy measure for expenditure because data are usually not available on expenditure by commodity in an agricultural research institution. Although still difficult to elicit, the allocation of scientific time by commodity is the most visible part of expenditure on agricultural research. Scientist years by commodity are (presumably) highly associated with total expenditure by commodity. Moreover, the results of the priority-setting analysis, based on scientist years, can be expressed in a way that is conducive for decision-making on research resource allocation. At the margin, large discrepancies in the ratios in Eq. (1) underscore the need to analyze a shift of resources from commodities with significantly higher scientist ratios than production ratios to commodities with significantly higher production ratios than scientist ratios.

However, the congruence approach *per se* cannot be expected to provide definitive information on research resource allocation. It can only contribute a framework for highlighting areas for further analysis. Significant departures from congruence warrant justification in terms of key considerations that are not reflected in economic importance. Commodities differ in their prospects for technological change, in the availability of alternative providers of research, and in their potential impact on other criteria, such as absolute poverty. Congruence analysis, thus, reflects only the status quo and may potentially hinder research investment that may be critical to the establishment of a rarely introduced commodity. Most of these weaknesses can be overcome with a more formal economic analysis of the potential impacts of alternative commodity programs.

3.2. *Efficiency-based priority assessment*

Economic surplus analysis is the most widely used means of *ex ante* evaluation of the efficiency 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 (i.e., lower unit costs of production) are estimated based on a parallel downward shift in the (linear) supply curve of a commodity (e.g., Mills, 1997; Mutangadura and Norton, 1999; Nagy and Quddus, 1998). Benefits vary depending on a number of factors, but the most important is the supply shift parameter, which depends on the expected yield and cost changes.

Research benefits and, to a large extent, the distribution of research benefits between producers and consumers, also depend on whether the market facing the commodity is assumed to be a small, open economy, or a closed economy. In much of sub-Saharan Africa (SSA) where infrastructure and markets are not well developed, most agricultural commodities are generally nontradable. In this study, only the markets for the major traded commodities—cocoa, cotton, rubber, and sesame—are modeled as small, open economies, with the markets for other commodities represented by closed economies.

The economic surplus empirical model for the small, open economy (Alston et al., 1995) used to calculate the potential economic benefits from a downward shift in the supply curve is given as

$$\Delta \mathrm{TS}_t = K_t P_0 Q_0 (1 + 0.5 K_t \varepsilon) \quad (2)$$

where $\Delta \mathrm{TS}_t$ is the change in total economic surplus attributed to research investment, K_t is the supply shift parameter, P_0 is the pre-research price, Q_0 is the pre-research quantity produced, and ε is the elasticity of supply of the commodity. For the closed economy model, the economic surplus is calculated as

$$\Delta \mathrm{TS}_t = K_t P_0 Q_0 (1 + 0.5 Z_t \eta) \quad (3)$$

where η is the (absolute value of) price elasticity of demand and Z_t is the proportionate decrease in price in year t, given as $Z_t = K_t\ \varepsilon/(\varepsilon + \eta)$.

The research-induced supply shift parameter K_t is the single most important parameter influencing total economic surplus resulting from unit cost reductions. Following Alston et al. (1995), the supply shift was derived:

$$K_t(\%) = \left(\frac{E(Y)}{\varepsilon(=1)} - \frac{E(PC)}{1 + E(Y)/100} \right) \times pA_t \quad (4)$$

where $E(Y)$ is the expected proportional yield increase or avoided yield loss per hectare or per animal, given that research is successful and the resulting innovation fully adopted; $E(PC)$ is the expected proportional increase or decrease in the variable production costs required to achieve the expected yield increase or avoided yield loss; p is the probability of research success; and A_t is the expected rate of adoption of the innovation at time t.

The change in total economic surplus in Eq. (2) is projected for a 20-year period from 2004 for research undertaken for the first 5–8 years. The projected benefits and research costs (C) over the 20-year period were discounted to derive the NPV of each commodity research program as

$$\mathrm{NPV} = \sum_{t=0}^{20} \frac{\Delta \mathrm{TS}_t}{(1+r)^t} - \sum_{t=0}^{20} \frac{\Delta C_t}{(1+r)^t} \quad (5)$$

where r is the discount rate. A discount rate of 5% was used in this study. Following Alston et al. (1995), efficiency-based research priorities were established based on the estimated NPV per unit of investment (i.e., NPV/C). The details of the data and data sources for the economic surplus model are discussed below.

3.3. Equity-based priority assessment

The major pathways through which agricultural research benefits the poor include: (1) direct effects on producers through increased productivity and incomes; (2) indirect effects on consumer welfare through lower consumer prices; and (3) employment and wage effects through increased labor demand. However, the relative importance of each pathway is very situation-specific. For example, the indirect market price effects of technical change on consumer welfare are more important in Asia where the highest concentration of poverty is among the landless laborers (Byerlee, 2000; Hayami and Herdt, 1977). In SSA, where a significant share of agricultural production is used for home consumption, the direct impacts on producers through increased home consumption are more important than the indirect effects on consumers (de Janvry and Sadoulet, 2002). Where a large part of agricultural production is directly used for home consumption, poor agricultural households are both producers and consumers, implying that they internalize much of the consumer surplus generated through research (Hayami and Herdt, 1977). The dominance of rural households producing largely for home consumption implies that the distribution of benefits between producers and consumers is less important than the distribution between poor and nonpoor households. The analysis of equity impacts thus focuses on estimating the relative research benefits to the poor. The first step involves setting the poverty line to identify the poor households and determine the incidence of poverty.

The economic surplus that would accrue to poor households (ΔTS_p) out of the total surplus (ΔTS) was first calculated as the sum of producer surplus (ΔPS_p) and consumer surplus (ΔCS_p) accruing to poor households based on their shares in total production (α_{ps}) and consumption (α_{cs}) of each commodity. The net economic benefits that would accrue to poor households (NPV_p) were then calculated in a similar fashion as follows:

$$
\begin{aligned}
\Delta\text{TS}_p &= \Delta\text{CS}_p + \Delta\text{PS}_p \\
&= \alpha_{\text{cs}}(\Delta\text{CS}) + \alpha_{\text{ps}}(\Delta\text{PS}) \\
&= \alpha_{\text{cs}}\left(\frac{\Delta\text{CS}}{\Delta\text{TS}}\right)\times\Delta\text{TS} + \alpha_{\text{ps}}\left(\frac{\Delta\text{PS}}{\Delta\text{TS}}\right)\times\Delta\text{TS} \\
&= \alpha_{\text{cs}}\left(\frac{\Delta\text{CS}}{\Delta\text{TS}}\right)\times\Delta\text{TS} + \alpha_{\text{ps}}\left(1-\frac{\Delta\text{CS}}{\Delta\text{TS}}\right)\times\Delta\text{TS} \\
&= \alpha_{\text{cs}}\left(\frac{\varepsilon}{\varepsilon+\eta}\right)\times\Delta\text{TS} + \alpha_{\text{ps}}\left(\frac{\eta}{\varepsilon+\eta}\right)\times\Delta\text{TS} \\
\Rightarrow \text{NPV}_p &= \alpha_{\text{cs}}\left(\frac{\varepsilon}{\varepsilon+\eta}\right)\times\text{NPV} + \alpha_{\text{ps}}\left(\frac{\eta}{\varepsilon+\eta}\right)\times\text{NPV}
\end{aligned}
\tag{6}
$$

where

$$
\frac{\Delta\text{CS}}{\Delta\text{TS}} = \frac{PQZ(1+0.5Z\eta)}{PQK(1+0.5Z\eta)} = \frac{Z}{K} = \frac{1}{K}\left(\frac{K\varepsilon}{\varepsilon+\eta}\right) = \frac{\varepsilon}{\varepsilon+\eta}.
$$

Estimates of the share of commodity production (α_{ps}) and consumption (α_{cs}) by the poor were derived from the household survey data. Technology adoption patterns among the poor, relative to the nonpoor, are already accounted for through the production share of the poor in allocating producer surplus between the two groups. That is, the production of each commodity is observed with adoption and hence reflects the current and possibly future adoption patterns. The data also revealed similar adoption patterns among poor and nonpoor households, with 28% of the poor using fertilizer, relative to only 25% of nonpoor households.

3.4. Price elasticities

Supply (ε) and demand elasticity (η) estimates specifically for Nigeria were not available. Alston et al. (1995) propose unitary supply elasticity in situations where a correct measure is not available. In view of the lack of reliable supply elasticity measures for Nigeria, we used unitary supply elasticity for all commodities. In a similar work on commodity priority setting for agricultural research in Colombia based on (relative) potential impacts on human nutrition, Pinstrup-Andersen et al. (1976) used unitary supply elasticity for all commodities on the basis of the fact that the long run supply elasticity of many agricultural commodities can be as large as one. They went on to test this with alternative low elasticity of 0 and high elasticity of 2 and concluded that although the absolute impact is sensitive to the supply elasticity assumption, this has little or no influence on the relative impacts and priorities.

Price elasticities of demand were estimated from the same household survey data, which included food consumption in addition to nonfood expenditures. Pinstrup-Andersen et al. (1976) applied the method developed by Frisch (1959) to estimate the price elasticities of demand on the basis of budget shares, income elasticities, and the flexibility of money. Following Pinstrup-Andersen et al. (1976), the direct price elasticities of demand (η), dropping subscripts for convenience, were thus estimated as

$$
\eta = \frac{\mu(1+\omega\mu)}{\lambda} - \omega\mu \tag{7}
$$

where μ is income elasticity of demand, ω represents budget shares, and λ is the flexibility of money. The value of the money flexibility parameter for Nigeria was derived using aggregate budget share (0.25) and income (0.61) and price elasticity (−0.49) estimates for cereals (Seale et al., 2003) as $\lambda = \mu(1-\omega\mu)/(\eta+\omega\mu) = -1.53$.

Pinstrup-Andersen et al. (1976) estimated income elasticities by regressing per capita quantity consumed on per capita real income. Building on this approach, we estimated income elasticities using the Heckman two-stage sample selection model to account for zero consumption. In the first stage, the probability of consumption of each food item was estimated using a probit model. The value of the dependent variable in the probit model equals one if the household consumed the food item during the survey period and zero otherwise. The vector of explanatory variables (Z) included per capita total expenditure (E) (in natural logarithm), household size, age, gender, education, and regional dummy. The inverse Mills' ratio (IMR) was then estimated as $\mathrm{IMR} = \phi\,(\alpha'\mathbf{Z})/\Phi\,(\alpha'\mathbf{Z})$, where ϕ is the probability density function, Φ is the cumulative distribution function, and α is the vector of probit estimates. The IMR was then used as an explanatory variable in a second-stage regression of per capita consumption to account for sample selection due to zero consumption. Specifically, per capita consumption (q) was regressed on a vector of explanatory variables (X), including per capita total expenditure (in natural logarithm), household size, age, gender, education, and the IMR. The regional dummy variable was excluded from the second stage for identification. As a proxy for tastes, preferences, and availability of particular food items, the regional dummy influences the decision to consume but not that of quantity of consumption, given the decision to consume.

The unconditional marginal effects of income on consumption were estimated as the sum of the conditional (on participation) marginal effects weighted by the probability of consumption and the marginal effect on the probability of consumption weighted by average conditional consumption (Huang et al., 1991). The income elasticities of demand (μ_i) were derived from the unconditional marginal effects as

$$\begin{aligned}\mu_i &= \left(\frac{1}{\bar{q}_i}\right)\left(\frac{\partial(q_i)}{\partial\ln(E)}\right) = \left(\frac{1}{\bar{q}_i}\right)\left(\left(\frac{\partial(q_i\,|\,q_i>0)}{\partial\ln(E)}\right)\right.\\ &\quad\left.\times\,\Phi(\alpha'\mathbf{Z}) + \left(\frac{\partial\Phi(\alpha'\mathbf{Z})}{\partial\ln(E)}\right)\times(\bar{q}_i\,|\,q_i>0)\right)\\ &= \left(\frac{1}{\bar{q}_i}\right)(\beta_E\Phi(\alpha'\mathbf{Z}) + \alpha_E\phi(\alpha'\mathbf{Z})[(\beta'\mathbf{X}) + \beta_{\mathrm{IMR}}(\alpha'\mathbf{Z})])\end{aligned} \tag{8}$$

where α_E and β_E are the estimated parameters of per capita total expenditure in the first and second stage regressions, respectively, and β_{IMR} is the parameter associated with the IMR.

4. Data sources and description

4.1. Technology-related data

Since the outcome of research investments will not be realized for many years, *ex ante* technology generation and adoption parameters can only be based on the opinions of experts in research and development who draw on a wealth of experience and knowledge in making informed predictions. Data relating to agricultural research and technologies were thus obtained primarily through small as well as large working group discussions involving researchers, research managers, and extensionists, with groups first organized around each commodity and plenary sessions organized later for all commodities and respondents. The expert opinions gathered during group discussions among commodity team members were later evaluated not only by larger groups at the plenary but also by the authors against historical records along similar lines of research. Specifically, a total of 144 national and international researchers, research managers, and extension workers were interviewed on the following: (1) number of years needed to generate the technology (i.e., research lag); (2) likely yield changes or avoided yield losses; (3) likely changes in input use, including labor, fertilizer, and chemicals; (4) probability of research success; (5) expected maximum adoption; and (6) the years until maximum adoption (i.e., adoption lag).

Expert opinions were elicited in an iterative, bottom-up fashion, with individual disciplinary, and commodity-based predictions challenged and the data refined in subsequent working group discussions. Working groups of researchers and extensionists were first formed to discuss research opportunities and prospects for each commodity based on specific technological interventions, which were under development with the available funding. The bases of comparison in predicting changes in several technology-specific parameters were the popular farmer practices for each commodity. Following elicitation of technology-specific data researchers and extensionists were asked to predict program level changes on the basis of the full range of technological innovations that would result from the respective commodity programs. The technology and program level potentials and predictions by the respective team members were finally subjected to reviews by larger group discussions organized for all respondents.

Benchmark historical records were used to guide the estimation of the various parameters. Yield changes were estimated for the whole package of improved varieties and the complementary crop and resource management practices. A clear distinction was made between genetic yield gains and yield changes associated with adoption of technological packages. Information on the probability of research success was also based on historical success rates of the various technologies within each commodity program. A simple workable approach was used where success was forecasted based on the proportion of successful technologies out of all that have been developed in terms of researcher as well as farmer perception of profitability and other attributes valued by farmers. Historical research and adoption lags and adoption profiles of the various technologies were used to guide estimation of expected research lags, adoption lags, and maximum adoption rates.

Case studies on adoption of various technologies conducted by the International Institute of Tropical Agriculture (IITA) and the national programs were already available. All available materials, published or unpublished, were consulted to refine estimates at several stages of the data collection process. The annual research costs for individual commodity programs were computed as the product of the respective number of FTE researchers and expenditure per FTE researcher. For comparison with research benefits expressed in US dollars at constant 2000 prices, the expenditure per FTE researcher of \$78,000 in 1993 international dollars was first converted to 2000 international dollars (\$94,000) and then to 2000 US dollars at official exchange rate.

4.2. Market-related data

Market-related data, including production and prices, were collected from a variety of sources. Agricultural production and price data for the period 2004–2006 were obtained from FAO (2007) agricultural statistical database. As noted earlier, while the same unitary price elasticity of supply was used for all commodities, the price elasticities of demand were derived from income elasticities that were first estimated from the same consumption and expenditure data forming the basis for this study. The estimated income and price elasticities are consistent with expectations, with food items of animal origin, for example, having higher income elasticities than staple food items.[1] The income elasticities are also in agreement with those of Seale et al. (2003) for commodity aggregates in Nigeria. For example, our income elasticity estimates of 0.78 for beef, 1.0 for dairy, and 1.06 for fish compare well with Seale et al.'s (2003) estimates of 0.84 for meat, 0.94 for dairy, and 1.02 for fish. The respective price elasticities of demand are similarly comparable. Table 1 presents the estimated price (and income) elasticities and the other technology- and market-related data used in the economic surplus analysis.

4.3. Household survey data

Agricultural research benefits to poor households were estimated from household survey data collected from a sample of 4,773 households (Kormawa et al., 2003). The survey gathered information on a range of variables, including household characteristics, agricultural production and input use, off-farm incomes, monetary and in-kind transfers, food and nonfood expenditures, and adoption of modern inputs. Table 2 presents socio-economic characteristics of the sample households. On the basis of a poverty line estimated at 105 Naira per capita per day from the household survey data on food and nonfood consumption expenditures, 61% of the 4,773 households surveyed were poor and had greater concentration in the savannas relative to the humid forest. It is interesting to note that poor households have nearly as much cultivated land and as large farm income share in total income as the nonpoor, implying that agricultural incomes are as important to poor households as they are to the nonpoor. Food consumption accounts for the largest shares of the expenditures of both poor (70%) and nonpoor (60%) households. Poor households have less educated heads than nonpoor households, but an equivalent proportion of poor (28%) and nonpoor (25%) households use fertilizer.

5. Results

5.1. Economic congruence

Table 3 presents commodity priorities according to economic importance, in terms of value of production, and actual resource allocations. Economic congruence requires that research resources be allocated in proportion to the economic importance of commodities. The top ten economically important commodities—in order of decreasing importance—include yam, cassava, sorghum, rice, citrus, millet, maize, poultry, leafy vegetables, and groundnut. The top ten commodities that actually receive the greatest share of the research resources are poultry, cassava, fish, oil palm, beef, dairy, yam, maize, cocoa, and sorghum. As the major staple and one with growing industrial importance, cassava features prominently in the actual portfolio receiving the second highest share of research resources. Therefore, the share of cassava in resource allocation is consistent with its share in agricultural production. Generally, however, there is a mismatch between actual allocations and those implied by economic importance. While actual allocations favor livestock (e.g., poultry, beef, and dairy), fish, and cash crops, the economic importance criterion would suggest greater allocations to the major food staples—yam, cassava, sorghum, millet, maize, and rice—and high value crops, such as citrus. The mismatch is partly due to the fact that allocations are first made across commodity groups—crops, livestock, fishery, and forestry—rather than individual commodities.

The patterns indicate that livestock, fish, and cash crops have high research intensity ratios in terms of resources per unit value of production, suggesting some scope for research resource reallocations to the major food staples and citrus with low intensity ratios. However, the congruence analysis assumes equal research opportunities for all commodities, with expected impacts per unit of investment assumed to be proportional to the value of production. As commodities actually differ in their prospects for technological change and hence potential economic impacts, further economic analysis is needed to provide more concrete information to assess the scope for research resource reallocation.

5.2. Efficiency measures and priorities

Table 4 presents commodity research priorities based on net economic benefits per unit of investment (the benefit–cost ratio). The top ten priority commodities in order of decreasing importance are cassava, maize, yam, rice, sorghum, millet, cowpea, groundnut, sweet potatoes, and leafy vegetables, with benefit–cost ratios ranging from 70 to 159 and rates of return of over 72%. In general, the major food staples are of high priority, whereas poultry, fruits, and vegetables are medium priority commodities, and other livestock, fish, and cash crops are of low priority. Although food staples are ranked high according to both economic importance and economic surplus criteria, most staples feature more prominently in the efficiency-based portfolio. For example, millet and cowpea are important staples for the poor in the dry savannas and are among the top commodities ranked according to the efficiency criterion.

5.3. Equity measures and priorities

The important determinant of the impact of agricultural research on poverty is the share of farm incomes in total

[1] The two-stage model estimates and marginal effects used in deriving the elasticities are available from the authors upon request.

Table 1
The data used in the *ex ante* impact analysis

Commodity	Production ('000 t)	Price (US$/t)	Price elasticity of supply (ε)	Price elasticity of demand (η)	Income elasticity of demand (μ)	Yield change (%)	Cost change (%)	Success probability (%)	Research cost (US$ m)	Research lag (year)	Adoption ceiling (percent area)
Beef	280	3,454	1	0.53	0.78	0.40	0.30	50	12.8	8	30
Cashew nut	186	1,133	1	0.95	1.45	0.35	0.15	50	3.7	8	40
Cassava	35,000	150	1	0.38	0.54	0.40	0.15	90	14.1	6	30
Citrus	3,250	600	1	0.45	0.67	0.25	0.15	50	4.0	8	30
Cocoa	380	975	1	Elastic	Elastic	0.30	0.15	50	8.5	8	40
Cotton	400	355	1	Elastic	Elastic	0.35	0.15	50	1.3	5	40
Cowpea	2,200	448	1	0.58	0.86	0.30	0.15	90	3.0	5	30
Dairy	432	329	1	0.65	1.00	0.40	0.25	50	12.8	8	30
Fish	370	1,600	1	0.71	1.06	0.30	0.20	50	11.3	5	30
Ginger	110	807	1	0.35	0.50	0.30	0.10	50	1.1	5	25
Goat	142	3,331	1	0.65	1.00	0.30	0.25	50	5.0	5	35
Groundnut	2,937	445	1	0.90	1.37	0.30	0.10	75	3.6	5	25
Leafy vegetable	4,300	317	1	0.45	0.68	0.25	0.10	50	2.4	5	25
Maize	5,150	309	1	0.54	0.77	0.35	0.15	90	5.3	5	40
Mango	730	605	1	0.45	0.67	0.25	0.15	50	2.1	8	30
Melon	347	622	1	0.45	0.67	0.25	0.10	50	0.7	5	25
Millet	6,100	318	1	0.28	0.42	0.25	0.10	75	4.2	5	30
Oil palm	1,239	868	1	0.95	1.45	0.30	0.15	50	14.5	8	30
Onion	615	412	1	0.29	0.44	0.25	0.10	50	0.8	5	25
Pepper	720	1,048	1	0.34	0.51	0.25	0.10	50	2.3	5	25
Pineapple	889	499	1	0.45	0.67	0.25	0.15	50	1.3	5	30
Plantain	2,110	431	1	0.44	0.67	0.30	0.15	75	4.4	8	30
Pork	191	1,909	1	0.65	1.00	0.35	0.30	50	1.1	5	30
Potato	133	369	1	0.20	0.30	0.35	0.15	75	0.5	5	30
Poultry	372	3,724	1	0.66	1.00	0.40	0.20	75	15.9	5	35
Rice	4,952	439	1	0.44	0.63	0.30	0.25	90	4.9	5	45
Rubber	112	754	1	Elastic	Elastic	0.30	0.15	50	3.1	8	30
Sesame	75	518	1	Elastic	Elastic	0.35	0.15	75	0.6	5	30
Sheep	97	3,450	1	0.65	1.00	0.30	0.25	50	4.0	5	35
Sorghum	8,100	310	1	0.28	0.42	0.25	0.10	75	4.2	5	25
Soybean	484	314	1	1.02	1.57	0.35	0.10	90	1.3	5	40
Sugarcane	548	114	1	0.95	1.45	0.30	0.15	50	3.0	8	30
Sweet potato	2,150	244	1	0.25	0.38	0.30	0.15	75	1.6	5	30
Tomato	889	280	1	0.29	0.44	0.25	0.10	50	0.8	5	25
Wheat	73	429	1	0.43	0.65	0.35	0.15	50	0.4	5	40
Yam	27,000	300	1	0.68	1.00	0.30	0.20	60	7.7	6	25

Source: FAOSTAT (2007); priority assessment survey; demand analysis by the authors.

household incomes. As noted earlier, poor households derive more than two-thirds of their incomes from farming, implying that agricultural research holds potential for poverty reduction. Agricultural research can generate greater benefits to the poor if scarce research resources are also allocated according to the relative impacts of alternative commodities. The relative impacts of alternative commodity research programs depend partly on the relative importance of commodities to poor households in terms of both production and consumption. However, whether introducing poverty criteria would in fact result in a shift in commodity priorities for poverty alleviation, as opposed to efficiency considerations, depends on whether there are commodities produced and consumed predominantly by poor households.

Table 5 presents the relative importance of commodities to poor households, both in production and consumption. In terms of production value, yam accounts for 28% of total production and is followed by cassava, maize, sorghum, millet, and cowpea. On the consumption side, maize is the most important, accounting for 20% of consumption, and is followed by yam, cassava, rice, beef, cowpea, fish, sorghum, and millet. Therefore, the major food staples are generally the most important to the poor both in production and consumption. As expected, subsistence production accounts for the greatest share of consumption of the major staples among the poor—such as sorghum (80%), millet (80%), maize (78%), yam (75%), and cassava (61%)—and implies that research on these commodities would have its greatest impacts directly through increased home consumption (de Janvry and Sadoulet, 2002).

Relative to their 61% share in the population, poor households account for the production of over 80% of soybean, implying that soybean is produced predominantly by poor

Table 2
Socio-economic characteristics of the sample households (means)

Variable	Poor households	Nonpoor households	All households
Sample size (*N*)	2,888 (61%)	1,885 (39%)	4,773
Cultivated land (ha)	2.86	3.12	2.96
Age of household head (years)	51	51	51
Household size	11	9	10
Education (years of schooling for the head)	3	8	5
Food consumption (% of total expenditure)	71	60	67
Farm income (% of total income)	66	74	69
Adoption of fertilizer (% adopters)	28	25	27

Source: Nigeria rural household survey (Kormawa et al., 2003).

households. On the other hand, poor households account for 50–65% of the production of major staples (cassava, maize, yam, sorghum, millet, and cowpea) and livestock. Clearly, there are no commodities that are produced and consumed predominantly by poor households. The production and consumption patterns thus suggest that the same commodities that are important to poor households are also equally important to the nonpoor.

Table 6 presents commodity research program priorities based on benefits to the poor per unit of investment. Consistent with their greater importance to poor households, the major food staples turn out to be of high priority according to the equity criterion. The top ten priority commodities in order of decreasing importance are maize, sorghum, millet, cassava, rice, cowpea, yam, soybean, groundnut, and sweet potatoes, with benefit–cost ratios ranging from 45 for sweet potatoes to 81 for maize. For example, one dollar invested in maize research would generate 81 dollars worth of additional food for the poor, relative to 154 dollars for all households. The poor would thus capture 53% of the benefits from maize research, relative to their 54% share in maize production. Given the size of the program, cassava research generates the greatest total benefits to the poor, but benefits per dollar invested are greater for research on maize followed by sorghum and millet.

On the other hand, poultry, fruits, and vegetables are medium priority commodities, whereas other livestock, fish, and cash crops are of low priority. Food staples are thus ranked high according to both efficiency and equity criteria, except that equity criteria favor cereals more than root crops. Given that soybean is produced mainly by poor households, it receives higher priority on the basis of equity than on efficiency and becomes one of the top ten commodities. Among the top priority commodities, however, the major staples are still more important because of their greater share in production and consumption by poor households. Given that commodities that are important to the poor are also important to the nonpoor, priorities are generally similar according to both efficiency and equity criteria. The commodities that poverty criteria would target for maximizing benefits to the poor are the same commodity that efficiency considerations would target for maximizing benefits to all households, suggesting that introducing a poverty dimension does not result in a major shift in research priorities. However, this should be examined further on the basis of the nature and magnitude of the efficiency and equity tradeoffs.

Table 3
Commodity research priorities implied by actual allocations and economic importance

Rank	Economic importance		Actual allocations	
	Commodity	Percent of production value	Commodity	Percent of FTEs
1	Yam	20.83	Poultry	11.52
2	Cassava	13.50	Cassava	8.51
3	Sorghum	6.46	Fish	8.23
4	Rice	5.59	Oil palm	6.58
5	Citrus	5.02	Beef	5.79
6	Millet	4.99	Dairy	5.79
7	Maize	4.09	Yam	4.66
8	Poultry	3.56	Maize	3.87
9	Leafy vegetable	3.51	Cocoa	3.85
10	Groundnut	3.36	Sorghum	3.66
11	Oil palm	2.77	Goat	3.62
12	Cowpea	2.53	Rice	3.53
13	Beef	2.49	Sheep	2.90
14	Plantain	2.34	Groundnut	2.61
15	Pepper	1.94	Millet	2.41
16	Fish	1.52	Cowpea	2.15
17	Sweet potato	1.35	Plantain	1.99
18	Goat	1.22	Citrus	1.83
19	Pineapple	1.14	Leafy vegetable	1.76
20	Mango	1.14	Cashew nut	1.68
21	Cocoa	0.95	Pepper	1.65
22	Pork	0.94	Rubber	1.40
23	Sheep	0.86	Sweet potato	1.15
24	Onion	0.65	Pineapple	0.97
25	Tomato	0.64	Mango	0.97
26	Melon	0.56	Soybean	0.94
27	Cashew nut	0.54	Cotton	0.92
28	Soybean	0.39	Ginger	0.80
29	Dairy	0.37	Pork	0.80
30	Cotton	0.37	Sugarcane	0.75
31	Ginger	0.23	Onion	0.55
32	Rubber	0.22	Tomato	0.54
33	Sugarcane	0.16	Melon	0.47
34	Potato	0.13	Sesame	0.45
35	Sesame	0.10	Potato	0.35
36	Wheat	0.08	Wheat	0.31

Source: Priority assessment survey; Beintema and Ayoola (2004); FAOSTAT (2007).

5.4. *Efficiency–equity tradeoffs and the scope for resource reallocation*

The tradeoffs as well as the scope for resource reallocation were analyzed using rank correlations of commodity ranked on economic importance, efficiency, and equity criteria, relative to actual priorities. Table 7 presents the program rankings and rank

Table 4
Agricultural research priorities based on economic benefits per unit of investment

Rank	Commodity	NPV/C (B/C ratio)	NPV (US$ million)	Rate of return (%)
1	Cassava	159	1993	85
2	Maize	154	747	94
3	Yam	124	847	78
4	Rice	116	513	86
5	Sorghum	113	432	85
6	Millet	106	400	83
7	Cowpea	99	266	81
8	Groundnut	90	296	79
9	Sweet potato	82	117	76
10	Leafy vegetable	70	155	72
11	Soybean	70	82	72
12	Onion	41	29	60
13	Pepper	41	85	59
14	Tomato	41	28	59
15	Melon	41	24	59
16	Citrus	39	134	48
17	Pork	37	37	57
18	Plantain	36	133	47
19	Poultry	35	498	56
20	Potato	32	14	54
21	Cotton	32	36	54
22	Wheat	20	8	45
23	Sesame	19	11	44
24	Mango	16	29	36
25	Pineapple	16	29	36
26	Ginger	12	12	37
27	Cashew nut	11	34	31
28	Goat	10	44	33
29	Sheep	8	31	31
30	Beef	8	87	27
31	Oil palm	8	96	27
32	Cocoa	6	43	24
33	Fish	6	60	27
34	Dairy	5	6	8
35	Rubber	2	6	16
36	Sugarcane	1	4	13

Source: Model results.

correlations of alternative commodity priorities. The efficiency and equity tradeoffs were thus examined using Spearman's rank correlation of commodities ranked on efficiency and equity criteria. Differences in research program rankings are thus a measure of the efficiency and equity tradeoffs. The Spearman's rank order correlation among the 36 commodities analyzed for the two criteria is 98%, confirming that the ranking of commodities on the equity criterion is similar to their efficiency ranking. As priority setting based on economic importance of alternative commodities does not account for differential prospects for technological change and hence impacts, the ranking according to the value of production is different from both equity and efficiency rankings, with a rank order correlation of only 55% with equity and 60% with efficiency. Despite the implied sub-optimality, priority setting based on economic importance provides a better approximation to efficiency- or equity-based priority setting than informal mechanisms that dictate resource allocations in practice. Indeed, with a rank order correlation of less than 6%, commodity rankings implied by actual allocations diverge considerably from optimal rankings on the equity as well as efficiency criteria.

The magnitude of the efficiency and equity tradeoffs and the scope for resource reallocation were further analyzed based on cumulated benefits to the poor as well as to all households as a proportion of total economic benefits. The ranking assumes a resource-constrained research system in which commodities are included incrementally according to their contribution to the selected decision criterion, as resources are added. Fig. 1 shows cumulative benefits to the poor as a proportion of total benefits from all programs as commodities were added according to their equity, efficiency, and actual ranking, each against the cumulative research costs as a proportion of the total budget. The analysis indicates that the poor would capture 45% of total research benefits, compared to their 53% share in total production, 40% share in total consumption, and 61% share in the population. The cumulative equity gains from the equity-based commodity research portfolio dominate the corresponding gains from the efficiency-based portfolio until 30% of the total budget has been allocated to the top seven commodities, but the efficiency–equity curves quickly converge and remain so afterwards. This implies that introducing a poverty dimension does not significantly change the commodity portfolio established on the basis of efficiency. The overall effect of equity-based priority setting—relative to efficiency—on research benefits to the poor is only 3% of total benefits to all households. That is, if programs were added only on their potential to maximize surplus for poor households, the additional benefit to the poor, over the efficiency criterion, would be at most 3%.

On the other hand, Fig. 2 shows cumulative benefits to all households as a proportion of total benefits from all programs as commodities were added according to their equity, efficiency, and actual ranking, each against the cumulative research costs as a proportion of the total budget. As expected, using the efficiency criterion in research targeting generates greater benefits to all households than pursuing equity objectives. However, overall research benefits from the efficiency-based portfolio dominate the corresponding gains from the equity-based portfolio only until 30% of the total budget has been allocated to the top ten commodity programs. The efficiency losses in terms of foregone benefits to all households are only 5% of total benefits. That is, if programs were added only on their potential to maximize benefits to the poor, foregone benefits to all households would be at most 5% of the total surplus.

Consistent with available evidence from other developing countries (e.g., Byerlee, 2000; von Oppen and Ryan, 1985), the results thus suggest that there are no significant efficiency–equity tradeoffs in agricultural research in Nigeria. Neither the additional benefits to the poor nor the foregone benefits to society are significant from prioritizing research according to equity—relative to efficiency—criteria. This is consistent with the observation that the major food staples are important

Table 5
Relative importance of commodities to poor households in production and consumption

Commodity	Importance to the poor		Subsistence production	Share of poor households over all households	
	Production (percent of total value)	Consumption (percent of total value)	Consumption (percent of . . . . consumption)	Production (α_{ps}) (percent of . . . production)	Consumption (α_{cs}) (percent of . . . . consumption)
Yam	28.00	13.00	75	56	32
Cassava	20.00	11.00	61	50	32
Maize	13.00	20.00	78	54	52
Oil palm	5.00	0.01	9	30	38
Sorghum	4.70	3.00	80	63	58
Cowpea	3.50	7.00	43	65	47
Millet	3.50	3.00	80	64	58
Goat	3.00	0.20	17	57	38
Onion	2.80	2.00	15	47	43
Rice	2.70	10.00	27	69	38
Beef	2.00	9.00	1	63	43
Sheep	2.00	0.20	17	61	38
Groundnut	1.80	2.00	29	66	36
Poultry	1.70	2.50	70	55	34
Cocoa	1.30	na	na	55	na
Citrus	1.20	0.01	39	34	34
Dairy	1.00	0.15	18	63	40
Pepper	1.00	2.00	43	64	47
Cashew nut	0.50	0.10	39	30	40
Melon	0.20	0.01	39	62	40
Soybean	0.20	0.10	13	84	46
Tomato	0.20	2.00	38	68	38
Cotton	0.05	na	na	41	na
Fish	0.05	6.00	5	41	40
Ginger	0.05	0.10	39	80	40
Leafy vegetable	0.05	1.00	70	41	39
Mango	0.05	0.01	39	41	40
Pineapple	0.05	0.01	39	34	34
Plantain	0.05	2.00	70	41	31
Pork	0.05	0.10	11	59	37
Potato	0.05	0.50	17	55	55
Rubber	0.05	na	na	28	na
Sesame	0.05	na	na	67	na
Sugarcane	0.05	na	na	28	na
Sweet potato	0.05	1.00	47	42	40
Wheat	0.05	2.00	5	56	43
Total (%)	100.00	100.00	50	53	40

Note: na = not available or not applicable.
Source: Computed from the Nigeria rural household survey data (Kormawa et al., 2003).

to both poor and nonpoor households in production and consumption. It is interesting to note, however, that the cumulative benefits to the poor from the optimal portfolios based on either equity or efficiency highly dominate the corresponding gains from the actual research portfolio. Relative to actual resource allocations, the overall effect of pursuing equity (efficiency) objectives in resource allocation on benefits to the poor is 14% (13%) of overall research benefits.

The results thus suggest that there is considerable scope for resource reallocation for enhancing the poverty impact of agricultural research. The levels of resource reallocation to or from each commodity were examined based on a comparison of actual allocations of FTE researchers and optimal allocations implied by efficiency and equity criteria. Table 8 compares actual and optimal resource allocations and presents the required reallocations implied by efficiency and equity criteria. Given the general mismatch between actual and optimal allocations, the required reallocations are significant for a number of commodity programs. Clearly, current resource allocations are biased in favor of cash crops and livestock and the results suggest reallocation of resources from these commodities to a number of food staples. The total reallocations range from 46% of the resources with the efficiency criterion to 50% with the equity measure. Specifically, resource reallocations to food staples range from 31% based on efficiency to 36% based on equity.

The scatter plot in Fig. 3 of the specific resource reallocations against the current allocations sheds more light on the

Table 6
Agricultural research priorities based on benefits to the poor per unit of investment

Rank	Commodity	NPVp/C (US$ million)	NPVp (US$ million)
1	Maize	81	394
2	Sorghum	67	255
3	Millet	63	237
4	Cassava	59	737
5	Rice	55	243
6	Cowpea	53	143
7	Yam	52	353
8	Soybean	46	54
9	Groundnut	45	148
10	Sweet potato	33	47
11	Leafy vegetable	28	62
12	Pepper	21	44
13	Melon	19	11
14	Tomato	18	13
15	Onion	18	13
16	Potato	17	8
17	Pork	17	17
18	Poultry	15	211
19	Citrus	13	46
20	Sesame	13	7
21	Cotton	13	15
22	Plantain	12	45
23	Wheat	9	4
24	Mango	7	12
25	Ginger	6	6
25	Pineapple	6	10
26	Goat	4	20
27	Beef	4	43
28	Sheep	4	14
29	Cashew nut	4	12
29	Cocoa	3	24
30	Oil palm	3	33
31	Fish	2	24
32	Rubber	1	2
32	Sugarcane	1	1
33	Dairy	0.3	3

Source: Model results.

options for refocusing commodity research for greater poverty reduction. Current allocations increase with distance from the vertical axis, with poultry, cassava, fish, oil palm, beef, and dairy thus commanding more resources than other commodities. Reallocations implied by efficiency and equity criteria increase with distance from the horizontal axis. In the lower quadrant are thus commodities that are currently commanding more resources than efficiency and equity criteria would suggest, such as poultry, fish, oil palm, beef, dairy, cocoa, and sheep and goat. The required reallocations from these programs range from about 2.5% (sheep and goat) to about 10% (poultry). In the upper quadrant are food staples, particularly maize, millet, soybean, sorghum, and cowpea, which are currently commanding less resources than efficiency and equity criteria would suggest. The average reallocation of resources to each of these programs ranges from 3.75% based on efficiency to 5% based on equity. The equity criterion thus suggests greater reallocations of resources to particular food staples than does the efficiency criterion.

Table 7
Commodity program ranking with alternative criteria

Commodity	Ranking according to			
	Equity (NPVp/C)	Efficiency (NPV/C)	Economic importance (value of production)	Actual allocation (FTE researchers)
Maize	1	2	7	8
Sorghum	2	5	3	10
Millet	3	6	6	15
Cassava	4	1	2	2
Rice	5	4	4	12
Cowpea	6	7	12	16
Yam	7	3	1	7
Soybean	8	11	28	26
Groundnut	9	8	10	14
Sweet potato	10	9	17	23
Leafy vegetable	11	10	9	19
Pepper	12	17	22	29
Melon	13	13	15	21
Tomato	14	15	26	33
Onion	15	14	25	32
Potato	16	12	24	31
Pork	17	20	34	35
Poultry	18	19	8	1
Citrus	19	16	5	18
Sesame	20	23	35	34
Cotton	21	21	30	27
Plantain	22	18	14	17
Wheat	23	22	36	36
Mango	24	24	20	25
Ginger	25	26	31	28
Pineapple	26	25	19	24
Goat	27	28	18	11
Beef	28	30	13	5
Sheep	29	29	23	13
Cashew nut	30	27	27	20
Cocoa	31	32	21	9
Oil palm	32	31	11	4
Fish	33	33	16	3
Rubber	34	35	32	22
Sugarcane	35	36	33	30
Dairy	36	34	29	6

Rank correlation	Equity	Efficiency	Economic importance	Actual allocation
Equity	1.00			
Efficiency	0.980	1.00		
Economic importance	0.552	0.606	1.00	
Actual allocation	0.013	0.056	0.718	1.00

Source: Tables 4 and 6; rank correlation analysis.

6. Conclusions and implications

Efficiency objectives aimed at maximizing economic surplus have been central to public agricultural research policy,

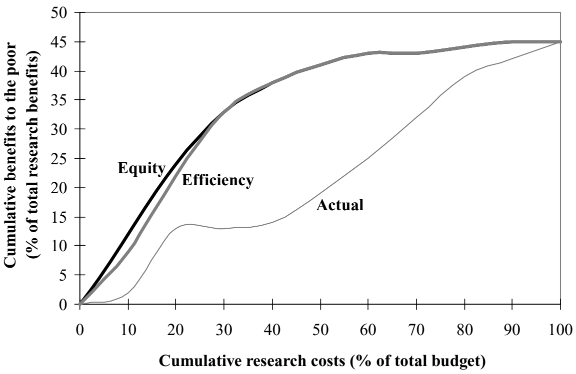

Fig. 1. Cumulative benefits to poor households from adding research programs according to their equity, efficiency, and actual ranking.

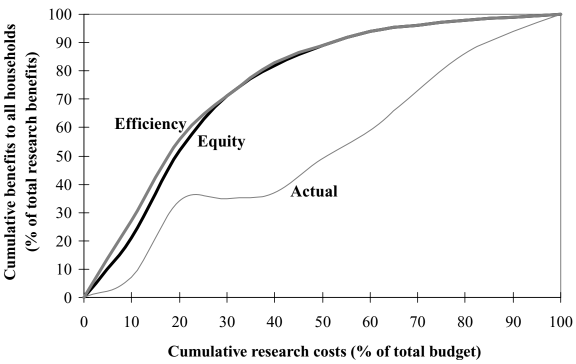

Fig. 2. Cumulative benefits to all households from adding research programs according to their equity, efficiency, and actual ranking.

but growing concerns about poverty have now required equity objectives to guide research planning for greater impacts on poverty. However, little is known about whether introducing poverty criteria would indeed result in a significant shift in research priorities. On the basis of projected economic and poverty impacts of alternative commodity research programs, this article assessed efficiency and equity tradeoffs and the scope for research resource reallocation in Nigeria. Relative to their 61% share in the population, poor households account for the production of 50–65% of major staples and livestock, but there are no commodities that are produced and consumed predominantly by poor households. The production and consumption patterns suggest that the same commodities that are important to poor households are also equally important to the nonpoor. In particular, the major food staples are generally the most important not only to the poor but also to nonpoor households, both in production and consumption. Subsistence production accounts for the greatest share of consumption of the major staples among the poor, implying that research on these commodities would have its greatest impacts on poverty directly through increased home consumption.

Consistent with their greater importance to poor households, the major food staples turned out to be of high priority according to the equity criterion. For example, the projected benefits

Table 8
Resource allocations and required reallocations implied by efficiency and equity criteria

Commodity	Allocations			Reallocations required	
	Actual	Efficiency	Equity	Efficiency	Equity
	(Percent of total FTE researchers)				
Poultry	11.52	2.05	1.85	−9.47	−9.68
Cassava	8.51	9.32	7.26	0.81	−1.25
Fish	8.23	0.35	0.25	−7.88	−7.99
Oil palm	6.58	0.47	0.37	−6.11	−6.21
Beef	5.79	0.47	0.49	−5.32	−5.30
Dairy	5.79	0.29	0.04	−5.50	−5.76
Yam	4.66	7.27	6.40	2.61	1.74
Maize	3.87	9.03	9.97	5.16	6.10
Cocoa	3.85	0.35	0.37	−3.50	−3.48
Sorghum	3.66	6.62	8.25	2.96	4.59
Goat	3.62	0.59	0.49	−3.04	−3.13
Rice	3.53	6.80	6.77	3.27	3.24
Sheep	2.90	0.47	0.49	−2.43	−2.41
Groundnut	2.61	5.28	5.54	2.66	2.93
Millet	2.41	6.21	7.76	3.80	5.34
Cowpea	2.15	5.80	6.52	3.65	4.37
Plantain	1.99	2.11	1.48	0.12	−0.51
Citrus	1.83	2.29	1.60	0.46	−0.23
Leafy vegetable	1.76	4.10	3.45	2.34	1.69
Cashew nut	1.68	0.64	0.49	−1.04	−1.19
Pepper	1.65	2.40	2.59	0.75	0.93
Rubber	1.40	0.12	0.12	−1.28	−1.28
Sweet potato	1.15	4.81	4.06	3.66	2.91
Mango	0.97	0.94	0.86	−0.03	−0.11
Pineapple	0.97	0.94	0.74	−0.03	−0.23
Soybean	0.94	4.10	5.66	3.16	4.72
Cotton	0.92	1.88	1.60	0.96	0.68
Ginger	0.80	0.70	0.74	−0.10	−0.06
Pork	0.80	2.17	2.09	1.37	1.29
Sugarcane	0.75	0.06	0.12	−0.69	−0.63
Onion	0.55	2.40	2.22	1.85	1.67
Tomato	0.54	2.40	2.22	1.86	1.68
Melon	0.47	2.40	2.34	1.93	1.87
Sesame	0.45	1.11	1.60	0.66	1.15
Potato	0.35	1.88	2.09	1.53	1.74
Wheat	0.31	1.17	1.11	0.86	0.80

Source: Model results.

to poor households per dollar invested in maize research suggest that the poor would capture 53% of the benefits from maize research, relative to their 54% share in maize production. While poultry, fruits, and vegetables are medium priority commodities, other livestock, fish, and cash crops are of low priority. Given that commodities that are important to the poor are also important to the nonpoor, priorities implied by efficiency and equity criteria are generally similar, with major food staples being of high priority in both cases. The results also suggest that introducing a poverty dimension into priority setting does not result in a significant shift in strategic priorities. The overall effect of equity-based priority setting (relative to efficiency) on research benefits to the poor is only 3% of total benefits, whereas the efficiency losses in terms of foregone benefits to all households are only 5%. Therefore, neither the foregone

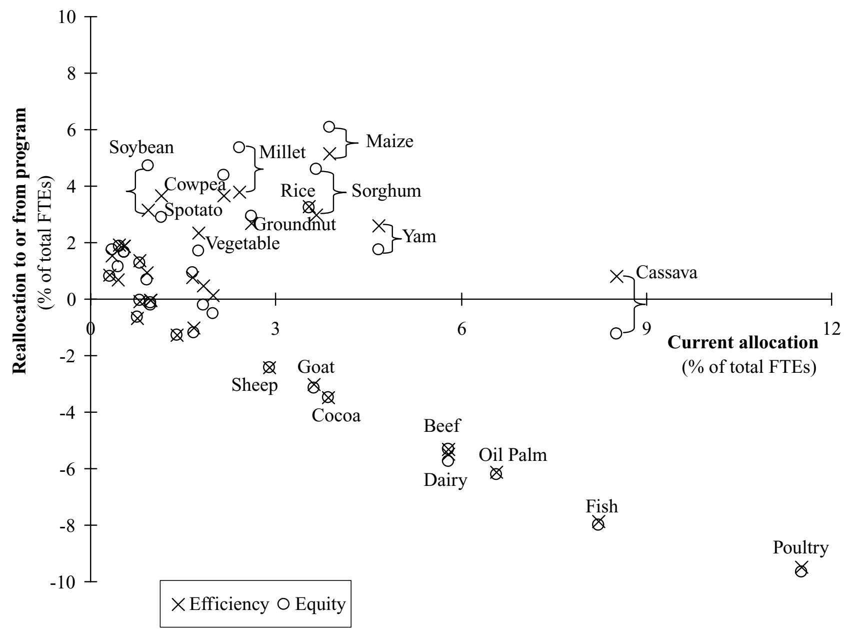

Fig. 3. Reallocation of research resources implied by efficiency and equity criteria.

benefits to society nor the additional benefits to the poor are significant from prioritizing research according to equity. This is consistent with the comparable importance of major food staples to both poor and nonpoor households in production and consumption. The analysis indicated that the poor would capture 45% of total research benefits, compared to their 53% share in total production and 40% share in total consumption. Therefore, there is no evidence that agricultural research would have significant differential potential impacts on poor and nonpoor households.

Although priority setting based on economic importance of commodities does not account for differential prospects for technological change and hence impacts, it provides a better approximation to a systematic priority setting than informal mechanisms, which Kelley et al. (1995) describe as "individual preferences and intuitive judgment" that dictate resource allocations in practice. Indeed, commodity rankings implied by actual allocations diverge considerably from optimal rankings on the equity as well as efficiency criteria. The overall effect of optimal priority setting on benefits to the poor is as high as 14% of economic benefits to all households. Regardless of whether efficiency or equity criteria are employed, the results suggest considerable scope for resource reallocation for greater impacts of agricultural research.

The patterns of resource reallocations implied by efficiency and equity criteria are similar, but the equity criterion suggests greater reallocations of resources to food staples than does the efficiency criterion. The results point to possible reallocation of resources from cash crops and livestock to the major staples, especially maize, millet, soybean, sorghum, and cowpea. It is important to note, however, that the required resource reallocations from cash crops and livestock do not imply overinvestment in these areas. Given the limited public research budgets, resource reallocations and greater refocusing would be the only option for maximizing research benefits to the poor. Research on food staples depends heavily on public funding, with little or no alternative support. On the other hand, as exporters and commercial farmers may gain substantially from research on particular commodities, the case can be made for private-sector research support for cash crops and livestock, such as cocoa, rubber, oil palm, and poultry.

Acknowledgments

We are very grateful to Will Masters and two anonymous reviewers for their very useful comments. We wish to thank P. Kormawa and R. Okechukwu for providing the household survey data used in this study. We are also grateful to IITA scientists and their national partners who generously provided information on their respective programs. We thank A. Olanrewaju and B. Ayedun for their research assistance.

References

Alene, A.D., Manyong, V.M., Tollens, E., Abele, S., 2007. Targeting agricultural research based on potential impacts on poverty reduction: Strategic program priorities by agro-ecological zone in Nigeria. Food Policy 32(3), 394–412.

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, Ithaca, NY.

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, DC.

Beintema, N.M., Ayoola, G.B., 2004. Nigeria, ASTI Brief No. 10, Agricultural Science and Technology Indicators (ASTI), IFPRI-ISNAR, Washington, DC.

Byerlee, D., 2000. Targeting poverty alleviation in priority setting for agricultural research. Food Policy 25, 429–445.

de Janvry, A., Sadoulet, E., 2002. World poverty and the role of agricultural technology: Direct and indirect effects. J. Dev. Stud. 38(4), 1–26.

FAO (Food and Agriculture Organization of the United Nations), 2007. FAOSTAT Agricultural Database.

Frisch, R., 1959. A complete scheme for computing all direct and cross demand elasticities in a model with many sectors. Econometrica 27, 177–196.

Hayami, Y., Herdt, R.W., 1977. Market price effects of technological change on income distribution in semi-subsistence agriculture. Am. J. Agric. Econ. 59(2), 245–256.

Huang, C., Raunikar, R., Misra, S., 1991. The application and economic interpretation of selectivity models. Am. J. Agric. Econ. 73(2), 496–501.

Kelley, T.G., Ryan, J.G., Patel, B.K., 1995. Applied participatory priority setting in international agricultural research: Making trade-offs transparent and explicit. Agric. Syst. 49, 117–216.

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.

Mills, B.F., 1997. *Ex ante* agricultural research evaluation with site specific technology generation: The case of sorghum in Kenya. Agric. Econ. 16, 125–138.

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.

Pinstrup-Andersen, P., de Londono, N.R., Hoover, E., 1976. The impact of increasing food supply on human nutrition: Implications for commodity priorities in agricultural research and policy. Am. J. Agric. Econ. 58(2), 131–142.

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

Seale, J., Regmi, A., Berstein, J., 2003. International evidence on food consumption patterns. United States Department of Agriculture, Economic Research Service. Technical Bulletin Number 1904.

von Oppen, M., Ryan, J.G., 1985. Research resource allocation: Determining regional priorities. Food Policy 10(3), 253–264.